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Long-term Residue and Water Management Effects on Soil Respiration and Soil Aggregate Stability in a Wheat-soybean, Double-crop System in Eastern Arkansas

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Abstract

Sustainability in agriculture is paramount to assuring continued production from our most naturally fertile soils. Storing carbon (C) in soil as organic matter through sustainable agricultural management practices can both remove atmospheric C and improve soil quality. The objective of this study was to evaluate the long-term effects of water management (irrigation and dryland), residue management [burn and no-burn, conventional (CT) and no-tillage (NT)] and residue/fertility level (high and low) on soil respiration and aggregate stability in a wheat- (*Triticum aestivum* L.) soybean [*Glycine max* (L.) Merr.], double-crop system in a silt-loam soil (Aquic Fraglossudalf) in the Mississippi River Delta region of eastern Arkansas after more than six years of consistent management. To this end, soil respiration was measured every two weeks during the 2011 and 2012 soybean growing seasons. A wet-sieving procedure was used to assess total and size-separated (i.e., 0.25-0.5, 0.5-1, 1-2, and > 2 mm diameters) water-stable aggregates (WSA). Soil respiration was greater under irrigation and CT on the majority of days sampled and averaged 27.4 and 16.3% greater than under dryland and NT management, respectively. Soil respiration was reduced by an average of 9.7% by residue burning, as compared to non-burning. The effects of residue level, achieved by differential N-fertilization, on soil respiration were inconsistent and generally non-significant. Soil water-stable aggregates were unaffected by burning, but were affected by all other field treatments. Total WSA concentrations were 19% greater under CT than NT within the dryland-low-fertility treatment combination. Total WSA concentrations under high-fertility were 18% less than under low-fertility within the irrigated-NT treatment combination, despite greater residue levels produced within the high-fertility treatment. The smallest two size classes (i.e., 0.25 to 0.5 and 0.5 to 1.0 mm) comprised over 80% of the total WSA. The WSA concentrations of the largest two size classes (1- to 2- and >2-mm) were unaffected by all treatments imposed. Understanding how long-term agricultural management practices affect

soil C storage and cycling can help improve policies for soil and environmental sustainability throughout the lower Mississippi River Delta region.

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Dedication

I wish to dedicate this thesis to a person who likely does not know how much of an impact he has had on my life. I would not have ventured into the area of environmental science if not for the time I spent with my high school sciences teacher, Mr. Tom Kennedy. His encouraging nature and endless fascination with the world inspired me to seek out knowledge and to always look for ways to help others. Mr. Kennedy was more than just a high-school teacher to many students in Mountain Home High; he was a friend, a confidant, and a mentor. He gave me direction and purpose when I was feeling lost and forlorn. I only wish I could adequately convey how much he helped me through our long after-hours conversations and his never-ending words of encouragement.

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Introduction

Agricultural sustainability rests on the principle that agriculture must meet the needs of the present population without jeopardizing the needs of future generations (Pretty, 2008). The maintenance and preservation of natural resources are essential to sustainable agriculture. Agricultural choices pertaining to residue and water management practices can have considerable impacts on long-term soil sustainability, as well as air and water quality. Because agricultural sustainability is, by definition, agriculture for the long-term, it is imperative to study the effects that agricultural practices have on soil, water, and air quality after an extended period of consistent management.

In a process generally known as the greenhouse effect, gases such as carbon dioxide (CO_2), methane, and nitrous oxide trap outgoing radiation inside the Earth's atmosphere, causing elevated atmospheric temperatures. According to the 2011 Environmental Protection Agency's Greenhouse Gas Inventory Report (EPA, 2013), a total of 6.3% of all U.S. greenhouse gas emissions were from the agricultural sector in 2011. Furthermore, this figure does not take into account emissions from fuel combustion and sewage emissions related to agricultural activities. Considering that the Mississippi River Delta region of eastern Arkansas is dense in land used for agricultural production, it is important to document the magnitude of greenhouse gas emissions from soils common to the area.

Carbon dioxide in the soil is produced through microbial, fauna, and plant root respiration. Soil respiration can be influenced by many environmental conditions, such as moisture and temperature (Franzluebbers et al., 1995). Generally, optimal conditions for soil respiration occur when the soil is warm and the soil water content is near field capacity. Environmental factors affecting soil respiration can be manipulated by residue- and water-management practices in agroecosystems. In general, management practices that promote plant biomass formation (e.g adequate fertility), increase the bioavailability of carbon (C) sources (e.g., tillage), and maintain optimal soil moisture for soil microbial activity (e.g., irrigation), will increase soil respiration rates. Total C loss from soil respiration in a particular location is controlled by a multitude of factors, including, but not limited to, plant and microbial communities, soil temperature and moisture levels, soil texture, available nutrients, soil structure, and soil organic matter (SOM) concentrations (Luo and Zhou, 2006). The relationships between soil respiration, soil environmental conditions, and land management are extremely complex; however, general trends from long-term studies can increase the capability to predict C loss through soil respiration.

An important mechanism for C sequestration in soil is aggregate formation. Aggregates are groupings of soil particles and organic matter held more tightly to each other than the surrounding particles (Kemper and Rosenau, 1986). Aggregate stability refers to the ability of an aggregate to withstand destructive forces such as tillage, raindrop impact, and erosion caused by wind and water (Kemper and Rosenau, 1986). Aggregate stability is important for controlling erosion and increasing infiltration, which promote healthy root growth and protect SOM. Soil aggregates provide physical barriers for soil organic C (SOC), reducing susceptibility of SOC to erosion, oxidation, and consumption by soil biota (Wander and Bidart, 2000). Soils with large inputs of organic material, and reduced physical disturbance, such as those created with no-tillage and non-burning practices, typically have greater amounts of water-stable soil aggregates (Six et al., 2000a). Therefore, it is important to understand how alternative management practices can affect the loss of C by respiration and the C storage capacity of the soils in eastern Arkansas as, in general, the more C that is present in the soil, the more fertile the soil will be in the long-term (Franzluebbers and Doraiswamy, 2007).

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Chapter 1

Literature Review, Justification, Objective, and Hypotheses

Literature Review

Soybean Production and Double-cropping Systems

In the United States, soybean [*Glycine max* (L.) Merr.] accounted for over 90% of the total national oilseed production in 2012 (USDA-ERS, 2013). Over 31 million hectares of soybean were planted in the United States in 2009, making soybean the second-most planted crop in the nation (USDA-ERS, 2013). Although most of the land planted to soybean is concentrated in the upper Midwest, a large amount of soybean production is located in the southern region of the Mississippi River Delta. Arkansas produces the greatest amount of revenue from soybean production of the three southern Delta states (i.e., Mississippi, Louisiana, Arkansas) and ranks 8th in national economic gain from soybean production (UACES, 2000). Soybean ranked second among the top agricultural commodities in Arkansas and soybean production is responsible for 16% of state farm receipts (USDA-ERS, 2013). The majority of Arkansas' row-crop land lies in the eastern part of the state, primarily in the Mississippi River Alluvial Plain (USDA-NASS, 2008).

Recently, over 20% of soybean grown in Arkansas was produced in wheat- (*Triticum aestivum* L.) soybean double-crop systems, where winter wheat is planted the fall prior to the soybean crop (USDA-NASS, 2008). Double-crop systems utilize a winter cover crop, which can increase revenue as a second annual cash crop while providing several other soil quality and pest-control benefits.

Benefits of double crop systems include those that are often associated with cover crops, such as pest suppression, increased water-holding capacity, reduced erosion, and increased soil organic matter (OM) (Dabney, 1998; Dabney et al., 2001; Bellinder et al., 2004). Cover crops can help control insects and plant disease by replacing the host plant with another crop that is not susceptible, thus removing the food source or breeding ground of unwanted pests (Anderson and Domsch, 1975). Cover crops also help suppress weeds by creating competition for sunlight by canopy shading, rather than leaving the soil surface bare.

Additionally, planting a winter crop can improve soil physical properties. Wind and rain erosive forces can destroy soil surface structure and cause surface crusting in the absence of plant residue cover. By protecting soil surface structure and improving surface roughness, cover crops also decrease runoff and sediment lost by surface water flow. In a study conducted by Brill and Neal (1950), increased infiltration and decreased runoff and erosion were observed in the presence of cover crops, even when conventional tillage (CT) was utilized, although no-tillage (NT) practices can further decrease runoff and erosion (Dabney, 1998). Cover crops are also useful for increasing the amount of organic matter returned to the soil, regardless of the tillage practice used. Double-cropped systems increase biomass production and promote soil organic matter (SOM) accumulation; however, double–cropping with winter wheat may result in less SOM gains than a non-harvested cover crop since some of the biomass generated by the winter crop is removed each year. Despite the numerous potential benefits, there are a few obstacles producers face in wheat-soybean, double-crop production systems.

A common disadvantage to double-cropping wheat with soybean is the short soybean growing season following wheat harvest. A shortened soybean growing season can limit the feasibility of double-cropping due to the potential impact on the most valuable crop's yield. A successful wheat-soybean, double-crop depends on choosing the right varieties and the right planting dates for the production area. An ideal soybean variety in this system is one that not only produces high yields, but also matures early to compensate for the shorter allotted growing period (Boahen and Zhang, 2006). Wheat is typically harvested during late spring in eastern Arkansas; therefore, soybean planting must be performed quickly to prevent soybean yield loss. Soybean yield losses can occur in the mid-south if planting is postponed later than mid-June (Sanford, 1982). In order to achieve an earlier soybean planting date, the wheat residue remaining after harvest is typically burned and mixed in by CT to prepare the seedbed for planting. Decreased yield, hence lower profit, in the soybean crop is still likely; however, the loss can be negated by extra income from wheat yields. In a study comparing the profitability of double- and single-crop systems in Mississippi, Kyei-Boahen and Zhang (2006) reported that, although the double-cropped soybean yields were 10 to 40% lower, the annual overall economic net returns were greater in the wheat-soybean, double-cropped system.

Importance of Soil Organic Matter

Soil organic matter is widely considered the most important indicator of soil quality as SOM has a major impact on other soil physical, chemical, and biological indicators of soil quality, such as bulk density, soil strength, infiltration, aggregate formation, cation exchange capacity (CEC), pH, electrical conductivity (EC), nutrient availability, and microbial biomass (Reeves, 1997). Soil quality is often used to describe the ability of the soil to carry out certain ecological functions important to sustaining a terrestrial ecosystem. Soil organic matter is the portion of organic matter in the soil that excludes undecayed or undecomposed animal and plant residues (Magdoff and Weil, 2004). The amount and forms of SOM in a soil are determined by the long-term balance of SOM gains and losses from the system. Soil organic matter is added and protected within the soil through plant biomass production, aggregation, humification, and deposition. Processes that remove SOM from the soil include soil erosion, leaching, and decomposition. Environmental factors, land management, dominant plant species, and soil properties govern the long-term balance of SOM in a particular soil. Long-term cultivation of soil generally reduces the total amount of SOM; however, the type of cultivation, climate, and soil texture heavily influence the magnitude and rate of SOM depletion. Soil organic material that has been lost from the soil can also be restored, or the rate of loss of SOM can be reduced, by conservation practices with high biomass return and reduced soil disturbance.

The Arkansas Delta Region is located in a humid sub-tropical climatic zone, where elevated moisture and temperature generally increase soil organic matter (SOM) decomposition and turnover rates. Soil organic matter (SOM) contents of the Mississippi River Delta region of eastern Arkansas are relatively low due to a long history of cultivated agriculture in the region, with mean

SOM and C contents of 0.21 g OM kg^{-1} and 1.12 g C kg^{-1}, respectively, in the top 15 cm of cropland soil (DeLong et al., 2003).

Soil Carbon Cycling

In addition to enhancing soil quality, SOM represents one of the largest reserves of C in the biosphere (Luo and Zhou, 2010). More than 75% of the earth's terrestrial C resides in soil and soils contain approximately 2500 Pg C to1-m depth, which is more than four times the amount of C stored in plant matter globally (Lal, 2004). Soil C storage and cycling play a substantial role in the global C budget, but certain aspects of soil C dynamics remain poorly understood.

There are many forms of soil C with a wide range of residence times in the soil. Most C in the soil is derived from plant matter, from both above-ground plant residues and root biomass. Soil organic C (SOC) is often divided into three pools: a labile pool that consists of microbial metabolites, simple carbohydrates, and organic acids with an estimated mean residence time (MRT) of days; a slow fraction made up of plant structural compounds like lignin, and physically protected C in aggregates with an estimated MRT of over 20 yr; and a recalcitrant SOC pool consisting of charcoal, humic compounds, and chemically stabilized C bound to soil minerals with an estimated MRT of over 1,000 yr (Jha et al., 2012). Complex interactions among physical, biological, and chemical processes within the soil as well as environmental interactions determine the amounts and actual residence times of C in a particular soil.

Carbon Loss Though Soil Respiration

Carbon in the soil can be lost through erosion, leaching of dissolved organic C, root and microbial decomposition, and carbonate dissolution. In the majority of soils, C loss is primarily due to soil respiration. Collectively, soil microbial decomposition and root respiration make up total soil respiration. Following gross primary production, soil respiration is the second largest flux of C between atmospheric and terrestrial ecosystems (Luo and Zhou, 2010). In a process known as photosynthesis, atmospheric C is converted into organic compounds within plant cells where the C can be used in structural plant tissues or broken down to supply the plant with energy via respiration. Plant root respiration can account for up to 80% of total soil respiration (Luo and Zhou, 2010). Dead plant material can be returned to the soil and broken down through microbial respiration to provide energy for soil microorganisms.

Technically, soil respiration, or CO_2 production in soil, cannot be directly measured in the field (Luo and Zhou, 2010). At steady-state, CO_2 production would equal soil surface CO_2 flux, but transport of gas in the soil is influenced within the soil profile and at the surface by gradient levels, porosity, water-filled pore space, wind speed, and a variety of other factors (Luo and Zhou, 2010). Non-steady-state conditions generally occur during mechanical disturbance or during a rainfall or irrigation event. Mixing of soil from bioturbation or tillage can release CO_2 trapped within soil pores and can disturb the CO_2 concentration gradient at the soil surface. Soil surface CO_2 flux can become exceptionally large as air is forced from the soil during rainfall or irrigation (Xu et al., 2004). With the exception of rainfall, irrigation, or a major physical disturbance, soil CO_2 production and soil surface CO_2 fluxes are nearly identical, especially if estimated using long-term measurements (Luo and Zhou, 2010).

The rate and total C loss from soil respiration in a particular location are controlled by a multitude of factors, including, but not limited to: plant and microbial communities, soil temperature and moisture levels, soil texture, available nutrients, soil structure, and SOM concentrations. Of the environmental controls on soil respiration, soil temperature and soil moisture are the most widely used when modeling and estimating soil respiration (Ryan and Law, 2005). There has been a plethora of studies showing a positive correlation between soil temperature and soil respiration (Lloyd and Taylor, 1994). Generally, soil respiration increases exponentially with temperature until it reaches a maximum at around 45 to 50°C, at which point soil microbial activity and plant root respiration become impaired (Luo and Zhou, 2010). Enzymes and essential proteins may begin to degrade in extremely high temperatures (i.e., > 50°C), sometimes causing long-term repression of soil respiration.

Soil moisture also directly controls soil respiration rates. Soil respiration is generally greatest when the soil moisture content is near field capacity. At field capacity, micropores (< 0.08 mm in diameter) in the soil are mostly filled with plant-available water and macropores (> 0.08 mm in diameter) are mostly air-filled, which facilitates diffusion of oxygen and soluble substrates (Luo and Zhou, 2010). Below field capacity, plant and soil microbial respiration can become water-limited. Additionally, water-soluble nutrients may also become less bioavailable and further reduce total soil respiration rates. When soil water contents are greater than field capacity, aerobic metabolism may become limited by oxygen availability as soil pores fill with water. Beyond this conceptual model of respiration dependence on soil moisture, the dynamic wetting-drying cycle of soil in the field can cause effects on soil respiration which are difficult to predict. In addition to the outgassing that occurs during a rainfall or irrigation event, soil respiration can be greatly stimulated by an influx of water following a period of dry conditions. Soil organisms and fine roots that die during periods of drought, as well as broken organo-mineral complexes, can become an easy substrate for microbial decomposition once soil moisture is non-limiting (Yuste et al., 2003). Further complicating matters, soil moisture and temperature are also correlated (Xu et al., 2004). For example, soil temperature drives evaporation rates and soil water content is a major influence on heat transfer and storage within soils.

The relationships between soil respiration, environmental controls, and land management are extremely complex. However, general trends from long-term studies can increase our predictive capabilities of soil respiration and our understanding of C cycling in soil. In addition to representing one of the main avenues of C loss from the soil, soil respiration also plays a major role in regulating atmospheric CO_2 levels. Understanding how land management and environmental factors influence soil respiration are, therefore, important for policy makers and land owners alike.

Carbon Storage in Soil Aggregates

Soil C can be protected from loss through chemical, biochemical, and physical processes (Six et al., 2002). Carbon compounds formed from oxidation (e.g., charcoal), within plants (e.g., lignin), or through biological transformation (e.g., polyphenols) are highly recalcitrant and are considered constituents of soil humus (Wershaw, 2004). Soil humus is defined as biologically stable organic matter that, due to its chemical composition, decomposes extremely slowly and is extremely persistent in soil (Wershaw, 2004). Recalcitrant forms of soil C can also form complexes with negatively charged clay particles in the soil, which further protects soil C against microbial decomposition and loss due to erosion or leaching. In addition to organo-mineral complexes, microbial exudates can further cement soil particles together and lead to the formation of stable soil structures that can enhance soil C storage.

Aggregates or peds are defined as groupings of soil particles and organic matter held more tightly to each other than the surrounding soil matrix (Kemper and Rosenau, 1986). Soil aggregates provide physical barriers to loss of SOM by reducing susceptibility to erosion, oxidation, and consumption by soil biota (Wander and Bidart, 2000). Aggregates are generally divided into two categories: microaggregates with diameters < 0.25 mm and macroaggregates with diameters > 0.25 mm (Six et al., 2004). Tisdall and Oades (1982) suggested a hierarchical model of aggregate formation in which microaggregates are formed when fungal, bacterial, and plant debris are bound together with soil particles. The microaggregates would then be bound together with less stable binding agents, such as roots and fungal hyphae to form macroaggregates. Oades (1984) later revised the aggregate formation model, postulating that microaggregates formed within macroaggregates. As the less-stable binding agents holding together macroaggregates disintegrated, microaggregates would be released, and the cycle would continue. Numerous studies have proposed variations of the Tisdall and Oades (1982) model for aggregate formation (Six et al., 2004). However, most agree that macroaggregates are the aggregate size-class most susceptible to disturbances, especially due to land-use changes following cultivation (Six et al., 2000a).

Increasing aggregate stability is especially important to enhancing soil quality and soil C sequestration. Aggregate stability is defined as the ability of an aggregate to withstand destructive forces such as tillage, raindrop impact, and erosion caused by wind and water (Kemper and Rosenau, 1986). Soils that have high concentrations of water-stable aggregates tend to have greater water infiltration rates, and are less prone to top-soil erosion, than soils with poor structural stability (Marquez et al., 2004). Increased macroaggregate turnover caused by mechanical disturbance or enhanced C mineralization can result in substantial soil C loss over time; however, the extent of land-use change impacts on soil physical structure is dependent on a multitude of factors such as soil history, climatic regimes, dominant plant species, and microbial community.

Agricultural Management Effects on Soil Respiration and Aggregation

Common management practices in wheat-soybean, double-crop systems in eastern Arkansas include wheat fertilization, residue burning, conventional tillage, and soybean irrigation. Although some short-term benefits such as loose soil for soybean seeding and root growth, increased drainage and infiltration early in the season, increased soil aeration, reduced stratification of herbicides and nutrients in the soil, and weed and disease suppression may come from CT and residue burning (UACES, 2000), there is a growing number of studies that indicate such practices may reduce soil quality over time (Tisdall and Oades, 1982; Six et al., 2000a; Chan et al., 2002; Malhi and Kutcher, 2007; Kasper et al., 2009; Anders et al., 2010). The effects of long-term soil fertilization and use of irrigation on soil C cycling are still relatively unknown. Due to a wide range of climates, historical land uses, and soil textures in wheat and soybean production systems, residue- and water-management effects on soil C cycling in these systems can be extremely site-specific. Therefore, it is important to understand how alternative management practices can affect the loss of C by respiration and the C storage capacity of the soils in eastern Arkansas as, in general, the more C that is present in the soil, the more naturally fertile the soil will be in the long-term (Franzluebbers and Doraiswamy, 2007).

Fertility/Residue Level Effects on Soil C Cycling

Through a symbiotic relationship with *Rhizobium* bacteria, soybean can fix nitrogen and therefore require little to no added N-fertilizer. However, proper tiller formation and optimal wheat yields depend on adequate soil-N concentrations. Loss of N through leaching and denitrification can be an issue in the warm and humid south; therefore, optimal split-applications of N at spring green-up and late-jointing wheat stages can help limit N loss and ensure desired wheat yields are achieved (Sripada and Weisz, 2009).

Nitrogen is a component of amino and nucleic acids and is essential to most biological activities. Greater N concentrations in the soil are generally correlated with enhanced plant growth rates and greater biomass production. Although N applications can increase plant biomass production, the long-term effects of N availability on litter decomposition and long-term SOM concentrations in the soil have been under some debate recently (Khan et al., 2007; Reid, 2008; Mulvaney et al., 2009; Powlson et al., 2010; Le Guillou et al., 2011).

While increased soil-N concentrations can stimulate microbial activity in most situations, high concentrations of N in the soil can inhibit lignin decomposition (Banger et al., 2010) and reduce microbial biomass (Lee and Jose, 2003) over time. Certain types of fungi (e.g., mycorrhizal fungi) are sensitive to mineral N applications (Hogberg et al., 2007). Following eight consecutive years of consistent management in a cottonwood (*Populus deltoides* Marsh.) and loblolly pine (*Pinus taeda* L.) plantation in Florida, yearly application of 50 kg N ha^{-1} yr^{-1}significantly reduced total microbial biomass over 20% and reduced soil respiration rates by approximately 10% (Lee and Jose, 2003). Although not significant, Lee and Jose (2003) also reported a strong trend of decreasing SOC with increasing N application rates within the same study. Allison et al. (2008) also observed suppression of protein- and chitin-degrading enzymes from N fertilization in a boreal forest in central Alaska, but no associated effect on soil respiration was noted.

Alternatively, increased biomass production can lead to greater SOC in the soil over time. In a wheat-containing rotation at the Central Great Plains Research Station in Colorado, 134 kg N ha^{-1} yr^{-1} increased SOC concentrations within the top 7.5 cm of a silt-loam soil by over 10% following 10 years of consistent management (Halvorson et al., 1999). A metadata study from 135 long-term (i.e., >10 yr) studies demonstrated that, although mineral-N additions did not significantly decrease SOC and N over time, N-fertilization did little to abate the negative effects of long-term cultivation on these soil properties (Churchman and Tate, 1986; Ladha et al., 2011).

After a 56-d laboratory incubation with a gently sieved silt-loam soil, the effects of wheat and miscanthus (*Miscanthus* x giganteus) straw residue amendments mixed with a range of mineral-N fertilizer rates (0, 60, and 120 mg N kg^{-1}) on water-stable aggregation were investigated by Le Guillou et al. (2011). At the end of the incubation period, the aggregate mean-weight diameter ($MWD = \sum w_i * x_i$, where i is the size fraction, w is the dry weight and x is the mean diameter) was reduced by over 45% when mineral-N was added to the soil, compared to when only straw was incorporated (Le Guillou et al., 2011). Fonte et al. (2009) also observed decreases of up to 40% in micro- and macro-aggregate concentrations following N fertilizer applications in a three-year experimental double-cropped wheat-corn system with straw amendments on a loam soil in Ghana. When decomposition is N-limited, as is usual with high C:N ratio residues like wheat, additional N can increase the formation of aggregate-stabilizing agents as microbial activity breaks down the wheat residue; however, N additions may decrease the role of fungi in binding and stabilizing soil aggregates (Bossuyt et al., 2001).

Increased N availability for soil microorganisms can boost soil respiration rates through biological stimulation (Xu and Wan, 2008; Morell et al., 2010); however, excess N applications can also have a negative effect on soil respiration rates (Lee and Jose, 2003; Bowden et al., 2004). Many studies involving cropping systems have reported either an inconsistent or general lack of an effect of N fertilization on soil respiration and C sequestration (Khan et al., 2007; Alluvione et al., 2009; Grandy et al., 2013; Skinner, 2013). In a Mediterranean barley (*Hordeum vulgare* L.) agroecosystem, Morell et al. (2011) observed increased soil respiration under N fertilization, but the effects were slight and limited to warm-wet conditions. Soil community structure alteration and decreased decomposition rates following long-term N amendments have been demonstrated, but primarily in forest soils (Lee and Jose, 2003; Bowden et al., 2004). In a fine-loamy soil in Michigan under a corn-soy-wheat rotation, Grandy et al. (2013) noted only slight decreases in soil respiration following N applications after four years of consistent management. In meta-data studies, both Liu and Greaver (2010) and Treseder et al. (2007) reported decreases of microbial biomass C by over 15% following N fertilization with concurrent declines in soil respiration rates. In a field study on a silt-loam soil in eastern Arkansas, N additions to create a high-wheat-residue treatment marginally decreased soil respiration rates (5.7%) compared to a low-residue treatment after two years of consistent management from the initiation of a wheat-soybean, double crop system (Brye et al., 2006).

Soil respiration responses to N fertilization reported in the literature are extremely varied and the effects of N fertilization on soil microbial properties are likely site specific. Given the complex way N can affect C cycling in soil; it may not be surprising that there is still no firm consensus on the long-term effects of N fertilization on soil C storage and soil respiration rates (Skinner, 2013).

The Effects of Residue Burning on Soil C Cycling

Prior to tillage and soybean planting, wheat residue left on the soil surface is commonly removed by burning from wheat-soybean, double crop systems in Arkansas. Although some have reported greater soybean germination rates and yields following residue burning (Hairston et al., 1987; Daniels and Scott, 1991), others have demonstrated little or no effect of burning on soybean yield (Rasmussen and Rohde, 1988). Cordell et al. (2007) reported no effect of wheat-stubble burning on soybean germination and yield two years after the initiation of a wheat-soybean, double crop system on a silt-loam soil in eastern Arkansas. Burning not only removes surface residue, but also produces hydrophobic ash that can reduce infiltration (Pikul and Zuzel, 1994) and hinder soil aggregate formation (Wuest et al., 2005). The bare soil surface following residue burning can also promote increased water loss by evaporation (Verhulst et al., 2011) and greater susceptibility of surface soil to erosion by wind and rain (Wuest et al., 2005). Residue burning directly impacts soil C cycling by the simple removal of C that would otherwise be returned to the soil. Additionally, years of annual burning can alter soil environmental properties that influence soil aggregation and C loss through respiration.

Retention of recalcitrant wheat residue can enhance soil structural stability by increasing soil C stocks and promoting growth of lignin-decomposing soil biota, such as mycorizial fungi, that help stabilize soil aggregates (Malhi and Kutcher, 2007). Although some long-term experiments, such as a 19-yr study in Australia (Chan et al., 2002), in which residue burning was determined to be detrimental to soil aggregate stability (Wuest et al., 2005), others have reported little to no short term (≤ 5 yr) effect on aggregation, aggregate-associated C, and aggregate-size distribution (Malhi and Kutcher, 2007; Wang et al., 2010). In a 19-yr long wheat-lupin (*Lupinus* L.) rotation on a clay-loam soil in Australia, Chan et al. (2002) observed significant reductions of up to 30% in both water-stable micro- and macro-aggregates when residue was removed by burning. Although long-term effects of residue burning may become substantial after several years, short-term effects of residue burning on soil aggregation were not observed after two years in a wheat-soybean, double crop system on a sandy-loam soil in eastern China (Wang et al., 2010). Removal of soil surface residue by annual burning may take years to drastically affect soil microbial community structures and influence soil structural stability.

Loss of C through burning directly removes C sources for soil decomposition and indirectly affects soil respiration by altering soil environmental conditions. Indirect effects of residue burning that can decrease soil respiration include: high moisture loss with no residue barrier (Verhulst et al., 2011), decreased aggregate stability (Chan et al., 2002; Wuest et al., 2005), decreased porosity of the soil surface crust (Pikul and Zuzel, 1994), and greater water-repellency, especially when coupled with NT practices (Roy and McGill, 2000; Morley et al., 2005; Doerr et al., 2009). Conversely, heat from burning surface residue andradiation exposure of the bare soil surface can increase soil microbial activity and boost respiration rates (Tate and Striegl, 1993). Knapp et al. (1998) reported up to 78% greater soil respiration in a tallgrass prairie caused by greater soil temperatures and stimulated root growth during the three months following a prescribed burn in Kansas. Soil respiration was unaffected by burning in the first two years after the initiation of a wheat-soybean, double-crop field study by Brye et al. (2006) on a silt-loam soil in eastern Arkansas. Residue burning may have a cumulative, but not immediate, impact on soil respiration from cultivated land. Few studies exist that examine long-term impacts of above-ground residue burning on soil respiration, especially in agroecosystems (Luo and Zhou, 2010).

Tillage Effects on Soil C Cycling

Reduced or no-tillage management practices have been well documented as highly effective ways to increase soil C storage and reduce soil surface CO_2 emissions in agroecosystems (Lal and Kimble, 1997; Ellert and Janzen, 1999; Schlesinger and Andrews, 2000; Sainju et al., 2008; Franzluebbers, 2010; Morell et al., 2011). Although CT can improve water infiltration and soil aeration in the short-term, mechanical disturbance of the soil can lead to reduced soil structural stability and greater soil bulk density over time (Reeves, 1997). Conventional tillage not only destroys internal soil structure by mechanical disintegration, but also increases decomposition of SOM by enhancing bioavailability to soil biota, thereby weakening the structure of larger aggregates in the plow layer.

The turnover rate from macro- to micro-aggregates is increased and soil physical stability is generally diminished by CT over time (Six et al., 2000a). Malhi and Kutcher (2007) observed a decrease in almost all aggregate size classes under CT compared to NT management from a 5-yr long canola- (*Brassica napus*) barley rotation on a silt-loam soil in Kansas; however, the effect of tillage on water-stable aggregates was most pronounced in aggregates with >2.5-mm diameters. Additionally, Mikha and Rice (2004) reported increased C and N concentrations within water-stable aggregates under NT compared to five years of CT. In a 19-yr long experiment in Austria where CT, reduced-, and minimum-tillage treatments were applied to a sandy-loam soil under a wheat-containing rotation, minimum tillage resulted in twice the amount of total water-stable aggregates than the other treatments (Kasper et al., 2009). Decreased disturbance of the soil can therefore lead to stable aggregate formation and potential soil C storage over time.

Conventional tillage can induce a substantial loss of CO_2 from the soil within the first few hours or days (Ellert and Janzen, 1999). In the short-term, tillage breaks apart soil aggregates and allows trapped CO_2 to escape into the atmosphere. Soil respiration rates reached 183 μmol CO_2 m^{-2} s^{-1} within 5 min after CT from a clay loam soil in Minnesota and gradually decreased down to 12 μmol CO_2 m^{-2} s^{-1} after 55 hr (Reicosky, 1997). Comparatively, soil respiration from NT changed very little and ranged from 1.3 to 4.4 μmol CO_2 m^{-2} s^{-1} during the same 55-hr period (Reicosky, 1997).

Additionally, tillage mixes surface residue in the soil where it is easily accessible to soil microbial attack. Both incorporated residue and previously protected C from within broken aggregates can sustain greater microbial respiration rates for long periods of time following CT compared to no- or reduced-tillage practices. In a study comparing CO_2 loss from a North Dakota sandy loam and an eastern Montana loam under pea (*P. sativum*), barley and rye (*Secale cereale* L.) rotations with CT and NT management practices, CT increased soil surface CO_2 production by 62 and 118%, respectively (Sainju et al., 2008). Brye et al. (2006) also observed a 37.6% greater respiration rate from CT than NT management within the first two years of a wheat-soybean, double-crop field study on a silt-loam soil in eastern Arkansas.

Increases in soil respiration by CT management practices are well-documented in short-term (i.e., < 5 yr) experimental studies (Alvarez et al., 1995; Brye et al., 2006; Gesch et al., 2007; Sainju et al., 2008; Celik et al., 2011); however, if tillage is used consistently over several years, reduced structural stability and loss of C storages can inhibit soil respiration (Balota et al., 2004). Following nine years of CT and NT management in a sorghum- (*Sorghum bicolor* L.) wheat-soybean rotation on a Texas silt-loam soil, Franzluebbers et al. (1995) reported 12% greater respiration rates from NT than CT management. Franzluebbers et al. (1995) attributed greater soil surface CO_2 emissions to enhanced water and heat retention from organic matter in the topsoil and better aggregate stability under NT.

Irrigation Effects on Soil C Cycling

In order to assure adequate soybean yields, most producers irrigate during the growing season on an as-needed bases (Bajaj et al., 2008). Alternatively, when water is unavailable or the implementation of irrigation is too costly, producers will practice dryland production, in which they rely solely on rainfall to water the crop. However, irrigation can be absolutely essential to producing adequate yields to meet economic demands, especially in a wheat-soybean, double-crop system.

Proper irrigation has been estimated to sequester SOC by a rate between 50 and 150 kg ha^{-1} yr^{-1} (Lal et al., 1999); however, irrigation can sometimes increase decomposition rates and reduce total SOM in seasonally dry soils. Churchman and Tate (1986) reported a decrease in total water-stable aggregates (TWSA) and soil C stocks after > 25 yr of irrigation of a seasonally dry, New Zealand silt-loam soil, which was likely due to increased microbial decomposition compared to dryland production. The sudden inundation of the soil by water from furrow irrigation, the most common irrigation technique, can also cause slaking to occur and unstable aggregates to disintegrate. The most unstable, larger aggregates are more affected by slacking due to irrigation than the aggregates that are smaller in diameter (Six et al., 2000b). An alternative water management practice is dryland production. Dryland production is used when water is unavailable for a field or the cost of water is too restrictive. Although physical disturbances can occur with irrigation, availability of water during the growing season can increase root and microbial biomass, which can negate the negative impacts of slaking on aggregate stability (Blanco-Canqui et al., 2010).

Lack of available water can cause yield reduction due to extended dry soil conditions. Since root respiration can account for up to 80% of total soil CO_2 emission (Luo and Zhou, 2010), plant biomass production and productivity that has been limited from water-stressed conditions can also greatly reduce seasonal CO_2 emissions. Although total season-long emissions may be limited by water-stressed conditions, a large pulse of CO_2 from the soil can follow a precipitation event when soil microbial activity is stimulated after a long dry period (Xu et al., 2004). Peak respiratory pulses on the order of 60 to 80 times the baseline respiration rate (about 0.10 to 0.3 μmol CO_2 m^{-2} s^{-1}) was reported following rainfall events in an annual grassland and a nearby oak-grass savanna on a rocky silt-loam soil in California (Xu et al., 2004). Sainju et al. (2008) determined previous soil water content and water retention as the two greatest determinants for soil CO_2 pulse intensities and duration following rainfall or irrigation in a North Dakota barley-pea rotation. Although many others have described similar soil CO_2 pulses after irrigation and rainfall events (Bauder and Schneider, 1979; Verma et al., 2005; Jabro et al., 2008), the intensities and durations have been extremely variable, even within the same study area (Rochette et al., 1991). The quality and composition of irrigation water can also have direct and indirect effects on soil respiration rates (Sarig et al., 1993). It is therefore important to study soil respiration rates under a range of water contents and environmental conditions in order to enhance the ability to predict global CO_2 fluxes from agroecosystems.

Justification

Ensuring the long-term sustainability of soybean-producing soils in the Mississippi River Delta region is an ever-increasing issue for soybean producers in Arkansas. As groundwater sources become depleted, fertilizer costs increase, and environmental perception and regulations become more severe, producers will need to look to alternative management practices that will ensure the sustainability and cost-effectiveness of their land. However, switching to alternative management practices can be a risky endeavor for soybean producers. Knowing the potential long-term benefits of switching to alternative management practices can help producers make informed decisions. These long-term benefits cannot be determined from short-term studies, such as those that are less than three years in duration, as many field studies involving crops are. Some trends in environmental conditions may change over time. For instance, in a study conducted by Amuri and Brye (2008) in a wheat-soybean, double-crop system, the soil bulk density under NT increased at a greater rate than under CT for the first three years, but then the bulk density under both NT and CT treatments decreased at a similar rate thereafter. If the study had only been conducted for three years, false conclusions might have been drawn regarding NT effects on soil bulk density.

With CO_2 and other greenhouse gas concentrations in the atmosphere becoming an increasingly concerning environmental issue, producers are being encouraged to reduce their carbon footprint. Fuel demands from fertilizer production and cultivation equipment as well as stimulated soil respiration from agroecosystems can contribute to rising atmospheric CO_2 concentrations. However, agronomic soils can serve as a C sink and help ameliorate the deleterious effects of increasing atmospheric CO_2 concentrations. Increased soil aggregation and SOM content are indicative of healthy, arable soil as well as a soil capable of trapping C that would otherwise be emitted into the atmosphere. Documenting the long-term potential benefits of alternative management practices for double-crop soybean production, such as refraining from burning wheat residue followed by NT soybean planting or dryland production, can ensure that producers are making educated management decisions that will positively affect their soil resource in the future. Furthermore, it is likely that alternative soybean management practices will result in at least similar crop growth, development, and yield compared to conventional management practices, while reducing operational costs and negative environmental impacts. In addition to improving soil quality and sustainability, some states have started to give monetary incentives to producers for continuing the use of or shifting to conservation field management practices due to soil C sequestration potential. A long-term, consistently managed field study would allow a glimpse into the potential future effects that some alternative, and possibly more sustainable, methods will have on the soil and soybean production in the lower Mississippi River Valley.

Objective and Hypotheses

Objective

The objective of this study was to determine the long-term effects of irrigation (irrigated and dryland), residue burning (burning and non-burning), tillage (conventional and no-tillage), and soil fertility/wheat residue level (high and low) on soil respiration, water-stable aggregation, and associated soil physical and chemical properties.

Hypotheses

Soil Respiration

Soil respiration is expected to follow seasonal trends which reflect changes in moisture and temperature levels as well as root activity. Differences in soil respiration due to burning and tillage are expected to be evident early in the soybean growing season and will likely decrease in magnitude near harvest time. It is hypothesized that the physical changes these treatments impose on the soil will reach equilibrium levels later in the soybean growing season. This is due to the fact that, although the soil microbial community structure might respond quickly to physical disturbance, changes in soil microbial activity might not be sustained over the entire growing season.

Alternative management practices that increase SOM and encourage microbial growth by regulating moisture and temperature, such as NT paired with no residue burning, are expected to increase soil respiration. When residue is retained and mixed into the soil by CT, soil respiration rates are expected to be greater than in NT due to increased bioavailability of the wheat residue to soil microbial decomposition.

Residue levels should have little effect on soil respiration, except when the residue is incorporated into the soil by CT and is therefore accessible as a substrate for the microbial community. Residue on the soil surface alone will likely not increase CO_2 flux much since the degradation process is much slower than for incorporated residue.

Burning, through removal of C sources and influence on soil water properties, is expected to reduce soil respiration during the season. The effect of burning is expected to be more apparent early in the soybean growing season. Irrigation provides soil biota and soybeans with the necessary water to perform biological functions and thus should increase soil respiration rates, especially during water-stressed periods. Estimated season-long CO_2 emissions are expected to respond similarly as daily soil respiration rates to treatments imposed. However, point-in-time measurements may not demonstrate the effect of alternative residue management practices as clearly as the total C emission from the soil during the growing season due to temporal and spatial variability of soil respiration.

Soil Aggregate Stability

Soil aggregate stability is expected to increase in all treatments with depth. Aggregates deeper in the soil profile are more protected from wind and water erosion. Clay content and older, more stable, SOM also reside below the soil surface and can promote greater aggregation with larger aggregate diameters compared to near the soil surface.

Aggregate concentrations are expected to increase with decreasing diameter. Smaller aggregates are typically held together by older, more stable SOM than the larger aggregates, which commonly are held by fresh organic matter and microbial exudates. Generally, soil aggregate stability increases with increasing concentrations of SOM. Practices that promote SOM, such as irrigation, high fertility/residue level, NT, and non-burning, should increase the amount of water-stable aggregates and aggregate- associated C and N concentrations. Conventional tillage is expected to reduce the concentration of aggregates with larger diameters compared to the concentration of small aggregates.

Irrigation is expected to increase total water-stable aggregate concentrations. Although the sudden inundation by furrow irrigation can cause slaking to occur and unstable aggregates to disintegrate, greater biomass production and biological activity under irrigation are expected to increase aggregate stability. The most unstable, larger aggregates are generally more sensitive to slaking; therefore, the concentration of water-stable aggregates in the larger aggregate size classes is expected to be less under irrigation than under dryland production.

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Chapter 2

Long-term Residue and Water Management Effects on Soil Respiration and Environmental Controls in a Wheat-soybean, Double-crop System

Abstract

One of the most significant contributors to the greenhouse effect is carbon dioxide (CO_2) gas in the atmosphere. Soil respiration, the combined production of CO_2 from soil, as a result of root and microorganisim respiration, is the second largest flux of CO_2 to the atmosphere from the terrestrial ecosystem. Agricultural management can greatly impact soil C storage and cycling. Therefore, the effects of water management (irrigation and dryland), residue management (burn and no-burn, conventional and no-tillage) and residue level (high and low) on soil respiration, soil temperature, and soil water content were examined over two consecutive years in a wheat-soybean double-crop system in a silt-loam soil (Aquic Fraglossudalf) in eastern Arkansas after more than six years of consistent management. Significant soil respiration differences among treatment combinations were observed on two and five dates out of the nine and 11 dates measured in 2011 and 2012, respectively ($P < 0.05$). Estimated season-long CO_2 emissions were unaffected by irrigation in 2011 ($P > 0.05$); However during the unusually dry 2012 growing season, estimated season-long CO_2 emissions were 87.6% greater under irrigation (21.9 Mg CO_2 ha^{-1}) than under dryland management (11.7 Mg CO_2 ha^{-1}; $P = 0.044$; LSD = 6.3). Estimated season-long CO_2 emissions under residue burning were 10.2% less (18.5 Mg CO_2 ha^{-1}) than under the non-burning (20.6 Mg CO_2 ha^{-1}; P = 0.032). Averaged over years and all other field treatments, estimated season-long CO_2 emissions were 15.5% greater under CT (21.0 Mg CO_2 ha^{-1}) than under NT (18.1 Mg CO_2 ha^{-1}; $P = 0.020$). The effects of residue level, achieved by differential N-fertilization, on soil respiration were inconsistent and generally non-significant. The relationship among soil respiration, 2-cm soil temperature, and 0- to 6-cm VWC, as determined using a multiple regression approach, was significant, but weak ($r^2 = 0.422$; $P < 0.05$). Water and residue management practices did not significantly affect the multiple regression coefficients generated from the whole data set, suggesting the environmental controls on soil respiration are only somewhat insensitive to water and residue management. Understanding long-term management effects on soil respiration and its

environmental controls in eastern Arkansas can help improve policies for soil and environmental sustainability throughout the lower Mississippi River Delta region.

Introduction

Greenhouse gases (GHG) in the atmosphere absorb and emit thermal infrared radiation that would otherwise escape the earth's atmosphere (i.e., the greenhouse effect). Intensification of the greenhouse effect by increased concentrations of atmospheric GHGs, primary carbon dioxide (CO_2), has been mainly attributed to anthropogenic sources (EPA, 2013). Atmospheric CO_2 concentrations, recorded at the Mauna Loa observatory in Hawaii, have increased by 76 μmol CO_2 mol^{-1} from 1960 to 2010 and reached 440 μmol CO_2 mol^{-1} in 2013 (Jones, 2013). The intergovernmental panel on climate change (IPCC, 2007) predicted the atmospheric CO_2 concentration to be between 730 and 1,020 μmol mol^{-1} by 2100. In the United States, sources of CO_2 emissions to the atmosphere include fossil fuel consumption (94.0%), natural gas systems (0.58%), ammonia production (0.16%), and long-term crop land management (0.14%; percentages estimated for 2011; EPA, 2013). Of the total GHG emissions in the United States, agricultural practices accounted for 6.9% in 2011 and agricultural soil management was determined to be largest source of GHG within the agricultural sector (EPA, 2013).

There is a growing worldwide interest in finding ways to reduce CO_2 emissions and to sequester and remove carbon (C) from the atmosphere. Optimizing agroecosystem management practices for soil sustainability can also help store carbon from the atmosphere in a semi-permanent state (Kirschbaum, 2000). Conventional agricultural management practices can severely impact ecosystem processes that control C cycling, often reducing C storages over time (McLauchlan, 2006; Franzluebbers and Doraiswamy, 2007; McCarl et al., 2007). Upon conversion to agriculture, soils can lose up to half of the C previously stored (Lal and Bruce, 1999), which generally occurs within the first 10 years after cultivation (EPA, 2013). A portion of the lost C can be restored over time by using less intensive agricultural management practices (i.e., no-tillage or reduced-tillage) and by promoting C assimilation from the atmosphere by increased plant productivity with adequate fertility, cover cropping, and/or irrigation. Consequently, C storage in agricultural soils is achieved by utilizing management practices that increase plant C inputs and slow microbial decomposition.

Collectively, microbial and root respiration make up total soil respiration. Soil respiration is the second largest flux of C to the atmosphere from terrestrial ecosystems, but is one of the least understood ecological processes driving the global C cycle (Luo and Zhou, 2010). Although it is important on an environmental and ecological level to be able to estimate and predict C loss by soil respiration, it can also be of great value for producers world-wide. Organic C reserves in the soil provide a multitude of benefits for crop production, including greater long-term nutrient levels (Magdoff and Weil, 2004), increased water infiltration and water- holding capacity (Wuest et al., 2005), lower bulk densities that promote root health (Fageria, 2012), and greater resistance to erosion (Balesdent et al., 2000). It is therefore important to understand how crop management practices can alter C loss via soil respiration, especially when these management practices are used over a long period of time. Soil aeration, moisture content, temperature, and soil organic carbon (SOC) content are a few of the many factors that control respiration rates below the soil surface, all of which can be greatly influenced by crop management practices (Ryan and Law, 2005).

In the United States, soybean [*Glycine max* (L.) Merr.] accounted for over 90% of the total national oilseed production in 2012 (USDA-ERS, 2013). Although most of the land planted to soybean is concentrated in the upper Midwest, a large amount of soybean production resides in the southern region of the Mississippi River Delta. Arkansas produces the greatest amount of revenue from soybean production of the three southern Delta states (i.e., Mississippi, Louisiana, Arkansas) and ranks eighth in national economic gain from soybean production (UACES, 2000). Soybean ranked second among the top agricultural commodities in Arkansas and soybean production is responsible for 16% of Arkansas farm receipts (USDA-ERS, 2013).

The majority of Arkansas' row-crop land lies in the eastern part of the state, primarily in the Mississippi River Alluvial Plain, also referred to as the Arkansas Delta region (USDA-NASS, 2008).

The Arkansas Delta region is located in a humid, sub-tropical climatic zone, where elevated moisture and temperature generally increase soil organic matter (SOM) decomposition and turnover rates. The average SOM concentration in the top 15 cm for the Arkansas Delta region is approximately 2.1% by loss-on-ignition (DeLong et al., 2003).

Recently, 22% of soybean grown in Arkansas were produced in a wheat (*Triticum aestivum* L.)-soybean, double-crop system, where winter wheat is planted the fall previous to the soybean crop (USDA-NASS, 2008). Since wheat is typically harvested during late spring, soybean planting must be performed quickly since yield losses in the mid-south can occur if planting is postponed later than mid-June (Sanford, 1982). Producers typically prepare a seedbed after harvesting winter wheat by burning the standing residue followed by conventional tillage in order to achieve an earlier soybean planting date. Other common management practices in wheat-soybean, double-crop systems in eastern Arkansas include wheat fertilization in the early spring and irrigation of the subsequent soybean crop as needed throughout the growing season.

Nitrogen fertilization of winter wheat in the spring of each year can cause two main effects: (1) increased wheat biomass and (2) greater N concentrations in the soil. Increased N availability for soil microorganisms can boost soil respiration rates through biological stimulation (Xu and Wan, 2008; Morell et al., 2010); however, excess N applications can also have a negative effect on soil respiration rates (Lee and Jose, 2003; Bowden et al., 2004). Nitrogen in the soil can inhibit lignin decomposition (Banger et al., 2010) and inhibit mycorrhizal fungal growth (Lee and Jose, 2003) when applications are greater than typical recommended rates. When just enough N is applied to supplement the needs of the crop without increasing soil N concentrations, root respiration and enhanced SOM concentrations can simultaneously boost soil respiration rates and soil C storage. High decomposition rates from elevated N applications can also reduce respiration rates over time by depleting long-term SOM reserves. Given the complex way N can affect C cycling in soil, it may not be surprising that there is still no firm consensus on the effects of N fertilization on soil C storage and soil respiration rates (Skinner, 2013). However, most studies on N effects on soil respiration have been on short-term experiments, often only focusing on the first few years after N applications.

Following wheat harvest in the spring, many producers choose to burn the remaining residue to facilitate an earlier soybean planting date. Additionally, burning can reduce crop disease and help control weed populations in the subsequent soybean crop (Amuri et al., 2010). The immediate volatilization of C and N from residue burning can add a substantial amount of GHGs to the atmosphere and can negatively impact soil quality over time. Aside from the loss of organic matter and nutrients, which otherwise would have been returned to the soil, burning removes the residue barrier and can also create hydrophobic properties at the soil surface(Roy and McGill, 2000; Doerr et al., 2009; Fageria, 2012). Since water and temperature are the main controlling factors on soil respiration, changes in water, gas, and heat movement at the soil surface can greatly influence soil C cycling.

Reduced- or no-tillage management practices have been well-documented as highly effective ways to increase soil C storage and reduce soil surface CO_2 emissions in agroecosystems (Lal and Kimble, 1997; Ellert and Janzen, 1999; Schlesinger and Andrews, 2000; Sainju et al., 2008; Franzluebbers, 2010; Morell et al., 2011). The mechanical disturbance caused by conventional tillage can induce a substantial loss of CO_2 from the soil within the first few hours or days (Ellert and Janzen, 1999). In the short term, tillage breaks apart soil aggregates and allows trapped CO_2 to escape into the atmosphere. Additionally, tillage mixes surface residue in the soil where it is more easily accessible to soil microbial attack. Both the surface residue and previously protected C from within broken aggregates can sustain greater microbial respiration rates compared to no- or reduced-tillage practices for longer periods of time. However, if tillage is used consistently over several years, reduced structural stability and loss of C storages can inhibit soil respiration (Balota et al., 2004).

In order to assure adequate soybean yields, most producers also irrigate during the growing season on an as-needed bases (UACES, 2000; Bajaj et al., 2008). Alternatively, when water is unavailable or the implementation of irrigation is too costly, producers will practice dryland production, in which the sole source of water to the crop is rainfall. However, irrigation can be absolutely essential to producing adequate yields to meet economic demands, especially in a wheat-soybean double-crop system. The lack of available water can cause a reduction or loss of yield from extended dry conditions. Since root respiration can account for up to 80% of total soil CO_2 emission (Luo and Zhou, 2010), plant biomass production and productivity that has been limited from water-stressed conditions can result in greatly reduced soil respiration rates and seasonal CO_2 emissions.

Although total season-long CO_2 emissions may be limited by water-stressed conditions, a substantial pulse of CO_2 from the soil can follow a precipitation event when soil microbial activity is stimulated after a long dry period (Xu et al., 2004). Peak respiratory pulses on the order of 60 to 80 times the baseline respiration rate were reported following rainfall events in an annual grassland and a nearby oak- (*Quercus douglasii)* grass savanna on a rocky silt-loam soil in California (Xu et al., 2004). Sainju et al. (2008) concluded that antecedent soil water content and water retention were the two greatest determinants for soil CO_2 pulse intensities and duration following rainfall or irrigation in a North Dakota barley (*Hordeum vulgare* L.) –pea (*Pisum sativum* L.) rotation. Although many others have described similar soil CO_2 pulses after irrigation and rainfall events (Bauder and Schneider, 1979; Verma et al., 2005; Jabro et al., 2008), the intensities and durations have been extremely variable, even within the same study area (Rochette et al., 1991). The quality of irrigation water can also have direct and indirect effects on soil respiration rates (Sarig et al., 1993). It is therefore important to study soil respiration rates under a range of water contents and environmental conditions in order to enhance predictions of global CO_2 fluxes from agroecosystems.

There are few studies that have examined the impacts of long-term (>10 yr) agricultural management practices on soil respiration rates, especially within the southern United States. Therefore, the objectives of this study were to i) evaluate the effects of irrigation (irrigated and dryland), residue burning (residue burning and no-burning), tillage [conventional tillage (CT) and no-tillage (NT)] and residue level (high and low) on soil respiration after 9 and 10 years of consistent management, and ii) evaluate the influence of soil moisture and temperature on soil respiration in a wheat-soybean, double-crop production system in the Mississippi River Delta region of eastern Arkansas on a silt loam soil.

It was hypothesized that management practices that increased biomass production (i.e., irrigation and high-residue), promoted residue retention (i.e., no-burning), and increased availability of C sources to soil fauna (i.e., CT) would result in greater soil respiration and subsequent CO_2-C emissions. Irrigation was hypothesized to only cause dramatic increases in soil respiration when soil moisture levels were limited [i.e., < 15% ($^v/_v$)]. It was also hypothesized that the relationship among soil temperature, soil moisture, and soil respiration would differ among treatment combinations since some management practices would also affect heat and moisture movement and microbiological diversity within the soil.

Materials and Methods

Site Description

This study represents an extension of a long-term study that was initiated in Fall 2001 at the University of Arkansas' Lon Mann Cotton Research Station (N 34°, 44', 2.26" and W 90°, 45', 51.56"), near Marianna, in east-central Arkansas. The soil at the site is a Calloway silt loam (fine-silty, mixed, active, thermic Aquic Fraglossudalf; (NRCS, 2013). The top 10 cm of the soil profile is comprised of 16% sand, 73% silt, and 11% clay (Brye et al., 2007).

The 30-year mean annual temperature and precipitation in the region are 15.6°C and 128 cm, respectively (NOAA, 2002). The 30-year minimum and maximum air temperatures in the area are 2.4°C in January and 32.8°C in July, respectively (NOAA, 2002).

Treatments and Experimental Design

The study site consists of 48, 3- by 6-m plots (Fig. 1). Initially, from 2001 to 2005, field treatments consisted of only CT and NT, residue burning and non-burning, and high- and low-residue levels (Cordell et al., 2007). The burn factor was arranged as a randomized complete block with two replications (Fig. 1). The tillage factor was a randomized complete block with three replications, stripped across burn treatments (Fig. 1). Different wheat residue levels were achieved with two different N fertilizer application rates as a split-plot factor within each tillage-burn combination (Fig. 1). The entire study area was furrow-irrigated from 2001 through 2004. However, at the start of the 2005 soybean growing season, a water management treatment (i.e. irrigated or dryland) was added as a fourth factor with a similar blocking structure as burning, thus confounding the two factors (Fig. 1). Furthermore, the original experimental design was split in half to accommodate the new water management factor, resulting in a lack of replication for comparing burning-irrigation treatment combinations. This design allowed for six replications for every burning-tillage-fertility treatment combination or six replications for every irrigation-tillage-fertility treatment combination.

Field Management

Before the field study was initiated in 2001, the study site was managed as a continuous soybean cropping system under CT. In preparation for this field study, the site was disked twice and fertilized with a broadcast application of 20 kg N ha^{-1}, 22.5 kg P ha^{-1}, 56 kg K ha^{-1}, and 1120 kg ha^{-1} of pelletized limestone for pH adjustments (Cordell et al., 2007). Wheat was drill-seeded at a rate of 90 kg seed ha^{-1} with a 19-cm row spacing in early to mid-November each year (Brye et al., 2007). In early March 2002 through 2004, all plots were manually broadcast fertilized with 101 kg N ha^{-1} as urea (46% N). An additional 101 kg N ha^{-1} was applied in the high-residue plots at the late-jointing state of wheat growth in approximately late March. Due to excessive moisture in Fall 2004, no fertilizer-N was applied during Spring 2005. In 2006 and each year since, only the high-residue plots were manually broadcast fertilized with 56 kg N ha^{-1} as urea in late February to early March the following spring. During the late-jointing stage, in approximately late March, wheat was fertilized again with a second application of 56 kg N ha^{-1} in the high-residue plots only. Since 2006, the low-residue plots received no additional N. Wheat was harvested with a plot combine in late May to early June each year.

Standing wheat residue was mowed to a height of 3- to 6-cm with a tractor-powered rotary mower in order to create a uniform surface layer of residue. Each year after mowing, the burn treatment was imposed by propane flaming. The tillage treatment was then imposed by disking two to three times to a depth of between 7- and 10-cm and then the soil surface was smoothed with a soil conditioner to break up soil clods.

A glyphosate-resistant soybean cultivar, maturity group 5.3 or 5.4, was drill seeded each year in approximately mid-June with a 19-cm row spacing at a rate of 47 kg seed ha^{-1}. Potassium (K) fertilizer was applied when needed at recommended rates (UACES, 2000). From 2005 to 2011, after soybean planting, a levee was established each year around the non-irrigated side of the study area to prevent water intrusion. Irrigated plots were furrow-irrigated based on visual observations of plant stress and soil moisture levels throughout the soybean growing season. Insects and weeds were controlled on an as-needed basis (UACES, 2000). Soybean was harvested each year with a plot combine between late October and early November. Each year, any remaining soybean stubble was left standing and unmanipulated prior to planting the subsequent wheat crop.

Soil Sampling, Processing, and Analyses

At wheat harvest, but before tilling and soybean planting, in 2011 and 2012, a single soil core sample was collected from the 6- to 10-cm depth from each plot, using a 4.8 cm diameter core chamber, beveled to the outside to reduce compaction, for determination of soil bulk density and other chemical soil properties. Samples were oven-dried at 70°C for 48 hr, crushed, and sieved through a 2-mm mesh screen. Soil C and N concentrations were measured by high-temperature combustion with an Elementar VarioMAX Total C and N Analyzer (Elementar Americas Inc., Mt. Laurel, NJ). The soil parent material is not calcareous, as determined by a lack of effervesce when mixed with dilute hydrochloric acid (Brye et al., 2007), thus all soil C was assumed to be SOC. Organic matter concentration was measured as percent loss-on-ignition (LOI) after 2 hr at 360°C (Schulte and Hopkins, 1996). Soil pH and electrical conductivity (EC) measurements were conducted with an electrode in a 1:2 soil/water solution. Subsamples were also analyzed with the Mehlich-3 procedure for extractable soil P and K (Mehlich, 1984).

Plant Properties

After wheat was harvested and the standing stubble mowed in mid-June each year, the amount of surface residue remaining was quantified in all plots by collecting all plant material from within a 0.5- by 0.5-m metal frame (0.25 m^2). Residue samples were oven-dried for 3-7 days at 55°C and weighed.

Soybean from the middle 1.5 m of each plot was harvested each year in late October with a plot combine. Soybean grain was air-dried for approximately three weeks and weighed. Grain subsamples from each plot were oven dried at 70°C for 48 hr to determine grain moisture. Grain yields were adjusted and reported based on 13% moisture content.

Soil Respiration Measurements

Throughout the 2011 and 2012 soybean growing seasons, beginning in late-June and ending in mid-October, soil respiration was measured approximately every 10 to 14 days. At least 24 hours in advance of a set of measurements, one 10-cm diameter polyvinyl chloride (PVC) collar with one beveled edge, was inserted manually at a random location in each plot to facilitate respiration measurements with the least amount of soil disturbance. Collars were moved within each plot after every third measurement, approximately every six weeks. Before each measurement, any green photosynthetic material inside the collar was gently removed to prevent CO_2 uptake during actual measurements. A portable infrared gas analyzer (LI-6400, LI-COR, Inc., Lincoln, NE) with a 10-cm diameter soil respiration chamber (LI-6400-09, LI-COR) attachment was used as per manufacturers' recommendations and similar to Brye et al. (2006) in a 2-yr study (i.e., 2003 and 2004), using the same plots as in this study, but shortly after study establishment. Once the soil chamber was placed on a collar, the CO_2 concentration in the headspace was scrubbed to approximately 25 mg L^{-1} below the ambient concentration by passing the air though a cylinder of pelletized soda lime. The actual efflux measurement started once the CO_2 concentration in the headspace of the chamber reached 10 mg L^{-1} below the ambient concentration and continued until the concentration was 10 mg L^{-1} above the ambient CO_2 concentration. Concurrent with each soil respiration measurement, the 2-cm soil temperature was measured using a pencil-type thermometer and the volumetric water content (VWC) from the 0- to 6-cm depth was measured using a Theta Probe (Model TH20, Dynamax, Houston, TX).

Measurements were generally conducted between 0700 and 1200 hr Central Time. Diurnal variations can have a large impact on measured soil respiration rates and can cause over- or under-estimation of total CO_2 production over time (Luo and Zhou, 2010). However, in general, soil respiration rates during mid-morning reflect a daily mean soil surface CO_2 flux (Luo and Zhou, 2010). Total season-long (i.e., planting to harvest) CO_2 emissions were estimated by linear interpolation between sample dates to calculate the area-under-the-curve using the trapezoid method (Reicosky, 1997; Morell et al., 2011).

Data Analyses

The irrigation factor was added in 2005 and, due to practical limitations of the study area, was superimposed on the burning factor with a similar blocking structure (Fig. 1). Therefore, irrigation and burning treatments are confounded within this experimental design and cannot be analyzed together. For this reason, two separate three-factor analyses of variance (ANOVAs) were conducted based on a strip-split-plot design, each excluding one of the confounding factors, using the PROC GLM procedure in SAS (version 9.2 SAS Institute, Inc., Cary, NC) to evaluate the effects of burning/irrigation, tillage, residue level, and their interactions on soil (i.e., pH, EC, C:N ratio, and soil C, N, P, K, SOM concentrations) and plant (i.e., residue level and soybean yield) properties. Sample date was included as a split-plot factor within residue level to perform a four-factor ANOVA based on a strip-split-split-plot design using the PROC GLM procedure in SAS to evaluate the effects of burning/irrigation, tillage, residue level, sample date, and their interactions on soil respiration, soil temperature, and VWC. All aforementioned analyses were conducted separately by year since there was dissimilar growing-season rainfall, soybean yields, and lengths of growing seasons between 2011 and 2012. When appropriate, means were separated using Fisher's protected least significant difference (LSD) at the $\alpha = 0.05$ level.

Year was formally included as a split-plot factor within residue level to perform a four-factor ANOVA based on a strip-split-split-plot design using the PROC GLM procedure in SAS to evaluate the effects of burning/irrigation, tillage, fertility, year, and their interactions on estimated season-long CO_2 emissions. Since rainfall amounts during June through August were only 27% of normal precipitation in 2012 and could be considered drought conditions, it was interesting to compare between water-stressed and favorable soybean growing seasons. When appropriate, means were separated using Fisher's protected least significant difference (LSD) at the $\alpha = 0.05$ level.

Combining across all field treatments, sample days, and years, correlations between VWC, soil temperature, and soil respiration rates were evaluated using JMP (SAS Institute, Cary, NC). Multiple regression analysis on the combined data set was performed to determine the effects of soil temperature and VWC on soil respiration using the standard least squares procedure in JMP Pro 10 (SAS). Variables were retained in the model based on their individual significance level ($P < 0.05$). The best-fit model generated from the multiple regression analysis was then fit separately to all 16 treatment combinations. A 95% confidence interval was calculated from the standard error associated with each model-predicted coefficient and used to assess differences among the models fit for each treatment combination. The relative importance of each coefficient was determined as the percentage of the total sum of squares attributable to each coefficient in the multiple regression analysis.

Results and Discussion

Soil Properties and Residue Levels

Few soil property differences existed among field treatments prior to the 2011 and 2012 soybean growing seasons. Soil C and N concentrations and soil C:N ratios were unaffected by any field treatment evaluated in this study in 2011 or 2012 prior to soybean planting ($P > 0.05$; Tables 1 and 2). Soil C concentrations in the top 10 cm averaged 9.7 and 10.8 g kg^{-1} in 2011 and 2012, respectively. Soil N concentrations in the top 10 cm averaged 1.1 g kg^{-1} in both 2011 and 2012. Soil C:N ratio averaged 8.7 and 9.5 for 2011 and 2012, respectively, in the top 10 cm. Since soil N concentrations were unaffected by residue level, which was achieved with differential inorganic N fertilization, it appears that there was little to no carry-over N in the high-residue treatment prior to soybean planting in either year to potentially impact early season soybean establishment and growth.

Soil P concentrations were unaffected by any treatment imposed in 2011, but differed among tillage and residue level treatments and among irrigation-tillage-residue treatment combinations in 2012 (*P* < 0.05; Table 1 and 2). When averaged over all treatments in the study, soil P concentration was 36.4 mg kg^{-1} in 2011. In 2012, soil P concentrations were 22 and 21% greater under CT (22.4 mg kg^{-1}) and low-residue (22.3 mg kg^{-1}) than NT (18.4 mg kg^{-1}) and high-residue (18.5 mg kg^{-1}), respectively (*P* = 0.046 and 0.002, respectively; Table 1). When burning was replaced with irrigation in the analysis, the effects of tillage and residue level on soil P concentrations were dependent on the irrigation treatment imposed in the 2012 growing season and ranged from 14.8 mg kg^{-1} in the irrigated-NT-high-residue to 26.0 mg kg^{-1} in the irrigated-CT-low-residue treatment combination (*P* = 0.013; Table 2). Soil P concentration threshold in irrigated and non-irrigated loessial soils for optimal soybean production are > 20 and > 13.5 mg kg^{-1}, respectively (UACES, 2000). In 2012, soil P concentration was 19.2% greater in the irrigated-NT-low-residue (17.7 mg kg^{-1}) than in the irrigated-NT-high-residue (14.8 mg kg^{-1}) treatment combination (LSD = 1.14), and soil P concentrations from both treatment combinations were slightly below recommended concentrations.

Soil K concentrations differed between irrigation (*P* = 0.009) and residue level (*P* = 0.006) treatments in 2011, but were unaffected by any treatments imposed in 2012 and averaged 62.8 mg kg^{-1} across all field treatments (*P* > 0.05; Tables 1 and 2). Soil K concentration was 29.5% greater under dryland management (75.3 mg kg^{-1}) than under irrigation (58.2 mg kg^{-1}) in 2011. Additionally, the low-residue treatment had a 12.2% greater K concentration (70.6 mg kg^{-1}) in the top 10 cm than the high-residue (62.9 mg kg^{-1}) treatment in 2011. All treatment combinations had soil P concentrations below Arkansas soybean production recommended K concentrations for optimal soybean production in loessial soils under irrigated and dryland management, which were > 110 and > 100 mg kg^{-1}, respectively (UACES, 2000).

Soybean yield loss can occur when the soil acidity of a silt-loam soil falls below a pH of less than 5.5 (UACES, 2000). Soil pH was marginally affected by residue-level and irrigation management in both years of this study ($P < 0.05$; Tables 1 and 2); however, all treatment combinations from both years had soil pH values within the recommended range (UACES, 2000). Soil pH averaged 6.3 and 6.7 and ranged from 5.8 to 6.8 and from 5.5 to 7.4 in 2011 and 2012, respectively.

Electrical conductivity is an indirect measurement that correlates with several soil physical and chemical properties, including of the amount of salts or ions in the soil solution (Grisso et al., 2009). Use of contaminated irrigation water can increase soil EC and salinity levels and cause substantial yield losses. Soils with an EC above 4 dS m^{-1} are considered saline and sub-optimal for agricultural production (Arshad and Martin, 2002). Soil EC differed slightly among burn-tillage-residue-level treatment combinations in 2011 ($P = 0.049$; Table 1) and also differed slightly among irrigation-residue-level treatment combinations in 2012 ($P = 0004$; Table 2); however, no treatment combination had a soil EC above recommended rates for soybean production in either year. Soil EC averaged 0.22 and 0.10 dS m^{-1} and ranged from 0.16 to 0.30 dS m^{-1} and from 0.04 to 0.22 dS m^{-1} in 2011 and 2012, respectively.

Soil organic matter was unaffected by any field treatments in 2011 (Tables 1 and 2); however, in 2012, SOM differed among irrigation-tillage-residue treatment combinations ($P = 0.035$). Soil organic matter concentration averaged 2.5% and ranged from 1.8 to 3.8% in 2011. Soil organic matter ranged from 2.2 in the irrigated-NT-low-residue to 2.6% in the dryland-CT-high-residue treatments when averaged over burning (Table 2).

Above-ground residue levels prior to tillage and soybean planting differed between residue-level treatments (i.e., the differential N fertilization) imposed in both years ($P < 0.05$; Table 1 and 2). Residue levels were 80.4 and 66.7% greater in the high- (8.3 and 7.0 Mg ha^{-1}) than in the low-residue (4.6 and 4.2 Mg ha^{-1}) treatment in 2011 and 2012, respectively.

Growing-season Environmental Conditions

In 2011, monthly rainfall for June through October ranged from 5.6 to 11.2 cm and was approximately 13% less than the 30-yr average monthly precipitation rates (NOAA, 2013; Fig. 2). In 2012, monthly rainfall ranged com 2.0 to 11.5 cm between June and October and was approximately 28% less than the 30-yr average monthly precipitation rates; however, rainfall in June, July, and August were less than half of the 30-yr normal, making 2012 unusually dry, and below-normal growing season conditions.

Average monthly air temperatures ranged com 16.2 to 28.6°C in 2011 and from 15.9 to 28.6°C in 2012 throughout the soybean growing season (i.e., June through October). Air temperatures in both years were comparable to the 30-yr averages within the same time period (NOAA, 2013; Fig. 2).

Treatment Effects on Soil Respiration

Soil respiration was highly variable within soybean growing seasons of the two years. Soil respiration rates ranged from 0.53 to 40.7 and from 0.17 to 13.1 μmol CO_2 m^{-2} s^{-1} throughout the 2011 and 2012 soybean growing seasons, respectively. The greatest soil respiration rates were observed early in the 2011 growing season, 25 days after planting (DAP) and was likely due to the rainfall that occurred the night before and the morning prior to measurement (Fig. 3). Extremely high soil respiration rates (i.e., > 30 μmol CO_2 m^{-2} s^{-1}) after rainfall have been reported by many others, indicating a precipitation-induced pulse caused by outgassing and/or stimulated microbial respiration preceded by water-stressed conditions (Lee et al., 2004; Xu et al., 2004; Borken et al., 2006). Peak respiratory pulses reaching 60 to 80 times basal respiration rates in a grassland ecosystem in California were reported by Xu et al. (2004) and soil respiration followed an exponential decline after the precipitation event which lasted more than 24 hours. The average and range of soil respiration rates measured during the two-year period of this study were generally consistent with those measured on other wheat- and soybean-containing agroecosystems

(Buyanovsky et al., 1986; Reicosky, 1997; Kessavalou et al., 1998; Brye et al., 2006; Drury et al., 2008; Hernandez-Ramirez et al., 2011). In one year or another or both, all field treatments evaluated in this study affected soil respiration ($P < 0.05$).

Burning and Tillage Treatment Effects on Soil Respiration

Soil respiration varied among burning-tillage treatment combinations over time in both years of this study ($P = 0.033$; Table 3). The effect of residue burning prior to soybean production was dependent on tillage treatment imposed and was only significant on one out of the nine sample dates in 2011 (Fig. 3). Under NT management, soil respiration was 39% greater under residue burning (12.9 μmol CO_2 m^{-2} s^{-1}) compared to non-burning (9.3 μmol CO_2 m^{-2} s^{-1}) at 25 DAP (Fig. 3). On the same date (25 DAP), soil respiration from the burning-CT (12.6 μmol CO_2 m^{-2} s^{-1}) was 25.3% less than from the non-burning-CT treatment combination (16.9 μmol CO_2 m^{-2} s^{-1}; LSD = 3.57; Fig. 3). Unlike in 2011, burning had no significant impact on soil respiration when compared within the same tillage treatment in the 2012 soybean growing season (Table 2; LSD = 4.38).

Although statistical differences between burning treatments within the same tillage treatment were few in 2011 and absent in 2012, there were some numerical trends worth noting throughout both years. In the 16 of the 20 sample dates across both years, soil respiration was numerically lower under CT management when the residue was burned than non-burned (Fig. 3). The removal of wheat residue by burning that would have otherwise been incorporated into the soil directly impacts soil respiration by limiting energy and nutrient sources for soil microorganisms and plants. Especially when combined with CT, burning can have detrimental effects on soil physical and chemical properties such as water retention, structural stability, and bulk density (Malhi and Kutcher, 2007).

Under NT management, soil respiration was also numerically smaller on 14 of 20 total sample dates in this study compared to non-burning (Fig. 3). However, the effect of burning on soil respiration was not as large or constant under NT than CT management. On six of the 20 sample dates, especially those early in the 2011 growing season, the burning-NT treatment combination had numerically greater soil respiration rates than when residue was neither burned nor mixed into the soil by CT (Fig. 3).

Few studies exist that have examined long-term impacts of residue burning on soil respiration, especially in agroecosystems (Luo and Zhou, 2010). Burning surface residue without any added mechanical disturbance can cause the same increased respiration rates as observed in grassland or prairie ecosystems, where grass seedling growth is stimulated by fire (Tate and Striegl, 1993; Knapp et al., 1998). Brye et al. (2006) conducted a similar study using the same field plots as this study in the first three years after this field experiment was initiated in which burning did not appear to affect soil respiration within the first few years after the site was converted from a conventionally tilled soybean-fallow cropping system in 2001. This indicates that residue burning may have a cumulative, but not immediate, impact on soil respiration.

The effect of tillage on soil respiration was dependent on the burn treatment imposed, but was only significant on seven of the 20 days sampled in 2011 and 2012 (Fig. 3). Soil respiration under CT (16.9 μmol CO_2 m^{-2} s^{-1}) was 82.4% greater 25 DAP than NT (9.26 μmol CO_2 m^{-2} s^{-1}) when residue was left unburned at the surface. In contrast, when preceded by residue burning, soil respiration under CT (6.68 μmol CO_2 m^{-2} s^{-1}) was 28.8% less than under NT (9.51 μmol CO_2 m^{-2} s^{-1}) by 48 DAP in 2011 (LSD = 2.57). On all of the sample dates in which tillage had a significant effect on soil respiration in the 2012 soybean growing season (i.e., 48, 61, 76, 95, and 106 DAP), CT resulted in between 29.3 and 138% greater soil respiration than NT when under residue burning (LSD = 1.05; Fig. 3). Additionally, soil respiration under NT (4.9 μmol CO_2 m^{-2} s^{-1}) was 23.4% less than CT (6.4 μmol CO_2 m^{-2} s^{-1}) by 95 DAP in 2012, when residue was not burned (LSD = 1.05; Fig. 3).

Conventional tillage generally increased respiration rates within both burning and no-burning treatments throughout this study (Fig. 3). When averaged over all other treatments, respiration rates under NT were numerically greater than CT on only five of the 20 days sampled.

Residue left on the soil surface in the non-burning-NT treatment combination could have both direct and indirect effects on soil respiration. As a direct effect, surface residue is less available to soil fauna for decomposition than residue that has been incorporated by conventional tillage. Indirectly, residue left on the soil surface can inhibit soil respiration by lowering temperature and by forming a physical barrier for gas exchange near the surface (Al-Kaisi and Yin, 2005). Soil 2-cm temperatures were affected by the burn-tillage treatment combination imposed in 2011 (P = 0.010) and 2012 (P < 0.001; Table 3). When residue was not burned, soil temperatures from NT were numerically smaller in 12 of the 20 sample dates than from CT (Fig. 3).

Greater peak growing-season respiration rates in CT than NT systems following rainfall events have been observed in other small-grain production systems without residue burning (Al-Kaisi and Yin, 2005; Al-Kaisi and Grote, 2007; Jabro et al., 2008; Sainju et al., 2008). In a similar study on a barley (*Hordeum vulgare* L.) system in North Dakota on a silt-loam soil, Sainju et al. (2008) reported that soil respiration was 1.5 to 2.5 times greater under CT than under NT following irrigation or rainfall. Curtin et al. (2000) suggested that large respiration rates in a CT system could be the result of CO_2 entrapment by a crust formed at the soil surface and a subsequent pulse release of CO_2 as the penetrating water pushed air out of the soil. However, it is more likely that incorporation of unburned wheat residue stimulated soil respiration by enhancing the availability of C substrate to soil fauna, especially under warm and wet conditions that favor microbial activity (Sainju et al., 2008).

When soil residue was burned prior to the act of tillage, the differences in soil respiration rates between NT and CT treatments were more pronounced during 2012 (Fig. 3), especially when rainfall and soil moisture were more limited (Fig. 2). Additionally, the burning-NT treatment combination had numerically smaller soil respiration rates than all other treatment combinations on nine of the 11 days sampled in 2012 (Fig. 3). The burning-NT treatment combination also tended to be slightly drier and warmer than the other treatment combinations (Fig. 3), perhaps caused by increased water repellency from years of organic matter combustion producing and concentrating hydrophobic substances at or directly below the soil surface (Doerr et al., 2009). Even a small influence on soil water infiltration during a period of dry conditions, as during the early part of the 2012 soybean growing season, could have caused major losses in soybean production. Moreover, water repellency of soils is often most severe soon after burning, recedes during periods of increased rainfall, and intensifies during warm and dry conditions (Roy and McGill, 2000; Morley et al., 2005). This may explain why differences in soil respiration between tillage practices following residue burning (Fig. 3) were less noticeable during the wetter 2011 soybean growing season than during the drier 2012 growing season (Fig. 2).

Presumably due to water-stressed conditions, the smallest soybean yield in 2012 of all burn-tillage treatment combinations was from the burning-NT combination (356 kg ha^{-1}; P = 0.005), whereas all other burning-tillage treatment combinations produced soybean yields that ranged from 582 to 639 kg ha^{-1} in 2012. Consequently, soybean root biomass and the contribution of root respiration to total soil respiration from the burning-NT were likely much less than in all other burning-tillage treatment combinations in 2012. Root respiration can account for 10 to 90% of total soil respiration, depending on root biomass, specific root respiration rates and type of vegetation (Luo and Zhou, 2010). Root respiration from soybean accounted for 49.7% of total soil respiration when averaged over a whole growing season in a clay-loam soil in Iowa (Hatfield et al., 2012). Therefore, even small changes in soybean development and biomass production can result in large impacts on total soil respiration rates.

Residue Level and Tillage Treatment Effects on Soil Respiration

Long-term annual application of N fertilizer affected soil respiration rates during both years of this study (P < 0.05; Table 3 and 4). Since burning and irrigation treatments are confounded and cannot be included together in a statistical analysis, separate analyses including each respective treatment were conducted, which resulted in slightly different interpretations regarding the statistical significance of the treatments and their interactions in this study (Table 3 and 4). With irrigation included in the statistical analysis, soil respiration was affected by residue level over time ($P = 0.023$) in 2011 (Table 4); however, when burning was included instead of irrigation, there were no effects of residue level on soil respiration in 2011 ($P > 0.05$; Table 3). Regardless if burning or irrigation were included in the statistical analysis, tillage ($P = 0.05$) and residue level ($P = 0.007$) affected soil respiration over time in 2012 (Table 3 and 4).

When coupled with CT, yearly urea-N applications to the winter wheat crop significantly affected soil respiration rate, but only on one of nine sample dates in 2011 (Fig. 4). Compared within CT, soil respiration was 42% greater under the low-residue (17.3 μmol m^{-2} s^{-1}) than the high-residue (12.2 μmol m^{-2} s^{-1}) treatment by 25 DAP in 2011 (LSD = 1.87; Fig. 4). Although N additions have been reported to cause a negative effect on some soil microbial decomposition processes (Bowden et al., 2004), total soil N concentrations in the top 10 cm did not differ between residue levels at the beginning of the 2011 soybean growing season ($P > 0.05$; Table 1 and 2). When combined with NT practices, soil respiration did not differ between residue levels on any sample dates in 2011 (Fig. 4). Many studies involving cropping systems have reported either an inconsistent or general lack of an effect of N fertilization on soil respiration and C sequestration (Khan et al., 2007; Alluvione et al., 2009; Grandy et al., 2013; Skinner, 2013). In a Mediterranean barley agroecosystem, Morell et al. (2011) observed that N fertilization increased soil respiration, but only slightly and only in warm and wet conditions. An effect of N enrichment on soil microbial community structure and litter decomposition rates, which reduced respiration rates over time, has been demonstrated, but primarily in forest soils (Lee and Jose, 2003; Bowden et al., 2004).

Soil respiration was numerically greater under CT on every sample date in 2012 compared to NT (Fig. 5). However, the difference in soil respiration between tillage treatments was only significant on four of the 2012 sample dates (i.e., 61, 76, 95, and 106 DAP; LSD = 0.57; Fig. 5). Soil 2-cm temperature also differed between tillage treatments over time in 2012 ($P = 0.015$; Table 4).

However, 2-cm temperatures were cooler by 0.7 and 1.2°C under CT (28.3 and 24.2°C) than NT (29 and 25.4°C) by 61 and 76 DAP (LSD = 0.5; Fig. 5), which may indicate that respiration rates were driven primarily by residue incorporation rather than temperature. Increased soil respiration under CT is well-documented in short-term (i.e., < 5 yr) field studies (Alvarez et al., 1995; Brye et al., 2006; Gesch et al., 2007; Sainju et al., 2008; Celik et al., 2011); however, long-term losses of SOM under CT may limit the substrate needed for prolonged soil microbial respiration. Before the initiation of this field study in 2001, the study site was under a soybean-fallow rotation with intensive tillage (Brye et al., 2007). Since then, SOM concentrations in this study have increased in all treatments over time, which can mainly be attributed to the addition of the winter crop and less intensive tillage practices (Amuri et al., 2008).

When either burning or irrigation was included in the statistical analysis, soil respiration was 35.9% greater under the low- (5.87 μmol CO_2 m^{-2} s^{-1}) than the high-residue treatment (4.32 μmol CO_2 m^{-2} s^{-1}) by 48 DAP in 2012 (LSD = 0.85; Fig. 6). This significant residue-level effect was preceded by a substantial rainfall event that interrupted a period of drought conditions that lasted more than two weeks (Fig. 6). In a fine-loamy soil in Michigan under a corn- (*Zea mays* L.) soybean-wheat rotation, Grandy et al. (2013) also noted decreased respiration rates following N applications.

Nitrogen additions in the high-residue treatment also marginally decreased soil respiration rates compared to the low-residue treatment in the first and second years after the initiation of this same field study (Brye et al., 2006). Brye et al. (2006) suggested that the lack of consistent differences between residue-level treatments was due to a failure to achieve statistically different wheat residue levels with differential N fertilization. However, the N fertilization produced significantly different wheat residue levels in both years in this study (Tables 1 and 2). However, soil N concentrations in the top 10 cm prior to soybean planting were unaffected by any treatment imposed in both years of this study, indicating that there was no carry-over N available during the soybean growing season. Therefore, any direct effects of mineral-N additions to soil biological function were likely to have occurred during the wheat growing season. The effect of N fertilization on soil respiration is still poorly understood (Grandy et al., 2013). Inorganic N additions can have a multitude of interactions with plant and microbial activity within the soil. When N is limiting, fertilizer applications can stimulate both microbial decomposition (Grandy et al., 2013) and plant growth and reduce soil aggregation (Fonte et al., 2009); however, N additions have been demonstrated to limit soil respiration (Bowden et al., 2004) by inhibiting lignin decomposition and reducing soil microbial biomass (Allison et al., 2008). Furthermore, soil microbial communities, which can be altered by N additions (Allison et al., 2008), have functional roles beyond decomposition, such as increasing soil structural stability, which in turn can protect and limit C loss from the soil (Le Guillou et al., 2011).

Irrigation and Tillage Treatment Effects on Soil Respiration

Similar to burning, soil respiration was also impacted by irrigation over time in both years of this study ($P < 0.001$; Table 4). Soil respiration also differed between CT and NT treatments within the water management treatments in 2012, the drier of the two years ($P = 0.047$).

Although irrigation affected respiration over time in both years sampled, soil respiration only differed between irrigation treatments on one sample day in 2011 (Fig. 7). Soil respiration under irrigation (10.5 $\mu mol\ m^{-2}\ s^{-1}$) was 31% less than under dryland management (15.28 $\mu mol\ m^{-2}\ s^{-1}$) 25 DAP in 2011 (LSD = 3.42; Fig. 7). However, partially due to the inherent nature of the experimental design used for this study and partially due to large variability, no differences between irrigation treatments were detectable on any of the sample dates in 2012 (LSD = 5.7; Fig. 7). Irrigation can have a direct effect on soil respiration by regulating available soil water for microbial and plant activity. Optimal soil moisture for plant and microbial function is generally around field moisture capacity, where the micropores (i.e., < 0.08 mm diameter) in the soil are still mostly filled with water and macropores (i.e., > 0.08 mm diameter) are mostly air-filled, which facilitates diffusion of oxygen (Luo and Zhou, 2010). Below this field moisture capacity, water and nutrients become limited, and when soil water contents are greater than field capacity aerobic metabolism is limited by oxygen availability. Permanent wilting point, when plants are unable to extract water from the soil, is approximately 15% ($^v/_v$) and saturation is near 40% ($^v/_v$) for Calloway silt-loam soils (Richards et al., 2005).

A noticeable increase in soil respiration from dryland management was observed following the large rainfall event at 25 DAP in 2011 (Fig. 7). Lee et al. (2004) also reported greater soil respiration pulse rates in water-stressed soils than from non-water stressed soil following rainfall events, such as the one preceding 25 DAP in this study. Post-rainfall stimulation of soil respiration in previously water-stressed soils could be caused by the combination of CO_2 displacement and increased decomposition of microbial biomass (Yuste et al., 2003). The irrigated soil may have also approached saturation, where oxygen limitation retarded respiration rates compared to the dryland soil. Overall, soil respiration under irrigation was numerically greater than under dryland management on 17 of the 20 sample dates of this study (Fig. 7).

In 2012, tillage effects on soil respiration were dependent on the water-management practice implemented ($P = 0.047$; Table 4). When under dryland management, soil respiration did not differ between tillage treatments; however, averaged over sample dates and all other field treatments, soil respiration was 30% greater under CT (4.19 μmol m^{-2} s^{-1}) than NT (3.22 μmol m^{-2} s^{-1}), under irrigation (LSD = 0.42). Averaged over sample date, 0- to 6-cm VWC also differed among irrigation-tillage treatment combinations ($P = 0.026$; Table 4). Volumetric water content was 9.5% greater under CT (0.23 cm^3 cm^{-3}) than NT (0.21 cm^3 cm^{-3}) management when compared under irrigation in 2012 (LSD = 0.02). However, 2-cm soil temperature did not differ ($P > 0.05$) among irrigation-tillage treatment combinations (Table 4). Additionally, soil respiration was always numerically greater under CT than NT in both years and in both irrigation treatments. Similar to measured fluxes, estimated season-long CO_2 emissions were also affected by burning, irrigation, and tillage treatments (Table 5 and 6).

Estimated Season-long Cumulative CO_2 Emissions

Total season-long CO_2 emissions differed between years ($P < 0.001$), tillage treatments ($P = 0.020$), burning treatments ($P = 0.032$; Table 5), and among irrigation-year treatment combinations ($P = 0.044$; Table 6). Although the 2012 growing season was longer (151 days) by 27 days than the 2011 growing season (124 days), cumulative CO_2 emissions were 32.7% greater in 2011 (22.3 Mg CO_2 ha^{-1}) than 2012 (16.8 Mg CO_2 ha^{-1}). Reduced respiration in 2012 was most likely caused by extended periods without adequate rainfall early in the 2012 soybean growing season, which reduced soybean growth and development, especially for the dryland soybeans. In addition, season-long (122 days) emissions from a soybean crop grown on a loam soil under CT in central Iowa were lower (12 Mg CO_2 ha^{-1}; Al-Kaisi and Grote, 2007), but still comparable to the findings of this study. Motschenbacher (2012) reported comparable seasonal CO_2 emissions in soybean, wheat, and corn rotations with rice ranging from 14 to 25 Mg CO_2 ha^{-1} from a silt-loam soil in the Mississippi River Delta region of eastern Arkansas.

Estimated season-long CO_2 emissions under residue burning were 10.2% less (18.5 Mg CO_2 ha^{-1}) than under the non-burning (20.6 Mg CO_2 ha^{-1}; Table 5). Burning may reduce CO_2 emissions by removing available soil C for microbial consumption via combustion. Residue burning may also have indirect negative effects on soil respiration, such as; greater moisture loss with no residue barrier (Verhulst et al., 2011), decreased aggregate stability (Chan et al., 2002; Wuest et al., 2005), decreased porosity of the soil surface crust (Pikul and Zuzel, 1994), and greater water-repellency, especially when coupled with NT practices (Roy and McGill, 2000; Morley et al., 2005; Doerr et al., 2009). It is important to note that the effect of burning on season-long CO_2 emissions was not dependent on sample year, indicating that reductions in CO_2 emissions from residue burning stay consistent regardless of growing-season changes in temperature and available moisture levels.

Averaged over years and all other field treatments, estimated season-long CO_2 emissions were 15.5% greater under CT (21.0 Mg CO_2 ha^{-1}) than under NT (18.1 Mg CO_2 ha^{-1}; $P = 0.020$; Table 3). Reduced- or no-tillage management practices are often considered one of the most effective means of reducing C loss by soil respiration (Lal and Kimble, 1997; Curtin et al., 2000; Al-Kaisi and Grote, 2007; Kimble et al., 2010). Both incorporation of residue and fractionation of aggregates containing protected C both can increase microbial decomposition rates. In a study comparing CO_2 loss from a North Dakota sandy loam and an eastern Montana loam under pea (*Pisum sativum* L.), barley, and rye (*Secale cereale* L.) rotations with tillage and no-tillage management practices, CO_2 emissions were 62 to 118% greater under NT across both locations (Sainju et al., 2008).

Averaged over all other field treatments, estimated season-long CO_2 emissions were 87.6% greater under irrigation (21.9 Mg CO_2 ha^{-1}) compared to dryland management (11.7 Mg CO_2 ha^{-1}; $P = 0.044$; LSD = 6.3) in 2012, but season-long CO_2 emissions were unaffected by irrigation in 2011 (Table 6). A substantial decrease in total seasonal emissions was expected from the dryland managed treatment in 2012 since conditions were unusually hot and dry early in the soybean growing season (Fig. 2).

Temperature and Moisture Dependence of Soil Respiration

Soil respiration was weakly correlated with linear terms for 2-cm soil temperature ($r^2 = .42$) and 0- to 6-cm VWC ($r^2 = 0.32$) as well as their quadratic terms ($r^2 = 0.42$ and 0.34, respectively). When combined across year, burning, irrigation, tillage, and fertility treatments, 42.2% of the variation in soil respiration was explained by VWC, 2-cm soil temperature, their interaction term, and their quadratic terms ($P < 0.05$; Table 7). The control of soil moisture and soil temperature on soil respiration is well-documented, where warm temperatures and water contents near field capacity generally increase CO_2 flux (Conant et al., 2000; Ryan and Law, 2005; Curiel Yuste et al., 2007; Li et al., 2008; Luo and Zhou, 2010). Despite the significant relationship, the model fit was not as accurate as expected. The residuals from the overall model also demonstrated a trend; as the predicted soil respiration rate increased, the corresponding residual deviation increased. The trend in the residuals points toward a more complex response of soil respiration in respect to temperature and moisture controls, which has been proposed by many others (Lloyd and Taylor, 1994; Conant et al., 2000; Raich and Tufekciogul, 2000; Fang and Moncrieff, 2001; Qi et al., 2002; Reichstein et al., 2003; Xu et al., 2004; Janssens et al., 2004; Ryan and Law, 2005; Curiel Yuste et al., 2007; Li et al., 2008; Peng et al., 2009; Phillips et al., 2011).

When all treatments were combined, the strongest predictive variable was the linear 2-cm temperature coefficient which explained 14.5% of the total sum of squares. Although 0- to 6-cm VWC was significant in the multiple regression model, both the linear and quadratic terms only explained 3.6 and 0.8% of the total sum of squares, respectively. Furthermore, the linear and quadratic VWC terms were generally non-significant when the model was fit separately for each treatment combination (Table 7). Brye et al. (2006) also reported a poor correlation between soil respiration and moisture content when a similar study was conducted on the same experimental site during the first two years after this same study was initiated. Additionally, using the same statistical approach on a silt loam soil in the same geographic region, Motschenbacher (2012) reported a significant but low predictive relationship between VWC, soil 2 and 10 cm temperatures, and soil respiration rates, where VWC was the weakest predictive variable in the model.

Using the best-fit model generated from all combined treatments, some general differences between soil temperature and moisture controls on respiration among treatment combinations could be ascertained by fitting the same multiple regression model separately to all 16 treatment combinations (Table 7). Although there were a few differences among treatment combinations in the number of coefficients that were significant in the model, there were few coefficients that fell outside of the 95% confidence intervals for the coefficients for the all-treatment model (Table 7). Only six of the 16 treatment combinations had coefficients that had ranges that fell outside of the all-treatment coefficients' 95% confidence interval range. Additionally, only four of the coefficients that fell outside of the corresponding all-treatment coefficient range were significant in their respective treatment combination model (Table 7).

Since few coefficients among treatment combinations deviated far from the all-treatments' model coefficients, it is likely that the moisture and temperature controls on soil were generally similar among individual treatment combinations. Thus, within a similar soil texture, plant and soil community, and climatic regime, a single multiple regression model using 2-cm soil temperature, 0- to 6-cm VWC, their interaction term, and their quadratic term, may be adequate for predicting CO_2 fluxes from various water and residue management practices in a wheat-soybean, double-crop production system.

Summary and Conclusions

After 9 and 10 years of consistent soil management, this study demonstrated that management practice effects on soil respiration varied with daily and yearly environmental conditions. Based on the 20 total sample dates over two years, there were few dates that had significant differences among treatment combinations. Many of the significant treatment combination effects were on dates following rainfall events or during uncommonly hot and dry conditions, indicating that treatment effects are more pronounced in times of extreme soil moisture and temperature ranges. Soil respiration under irrigation and CT were greater on a majority of sample dates and averaged 27.4 and 16.3% greater than dryland and NT management throughout the study period. Residue burning resulted in less soil respiration than non-burning on a majority of sample dates and resulted in an average decrease of 9.7% when compared to no-burning management over the sample period. Soil respiration was generally unaffected by residue level.

Estimated season-long CO_2 emissions were affected by burning and tillage in both years. The impact of irrigation on seasonal CO_2 emissions differed between years. Results indicated that burning and NT management generally had lower seasonal emissions during both favorable and drought-stressed soybean growing seasons. Irrigation, however, only affected estimated season-long CO_2 emissions during water-stressed conditions by supplementing adequate soil moisture for soybean growth and soil microbial respiration.

The relationship among soil respiration, 2-cm soil temperature, and 0- to 6-cm VWC, as determined using a multiple regression approach, was significant, but weak. Individual treatment combinations did not appear to dramatically affect the predictive relationship of soil respiration from soil temperature and VWC.

Overall, results of this study indicate that agronomical management practices that have the ability to enhance C formation and storage, such as non-burning and irrigation, may lead to a large loss of soil C via soil respiration, especially when coupled with CT practices. Nitrogen fertilizer to generate differential residue levels did not appear to have a consistent effect on soil respiration even though wheat-residue levels were significantly greater in the high-residue treatment each year. Reductions in daily CO_2 flux and season-long CO_2 emissions from soil under NT management observed in this study was consistent with that reported in the literature. Although slow increases in soil C over long periods of time might produce greater respiration rates, soil C and SOM concentrations in the top 10 cm were generally similar in all treatment combinations in each of the two years of this study. Even though this study is conducted after 9 and 10 years of consistent management, equilibrium levels of soil C and SOM may not be established yet.

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Appendices

Appendix 1: Example SAS program for strip-split model and relevant data files.
(Used for bulk-soil properties, wheat residue levels, soybean yields, ect.)

```
title 'Sharon Faye Smith: ANOVA FOR strip-split analyses';
data SoilProp;
 infile 'SoilProp.csv' firstobs = 2 delimiter = ",";
 input plot tblock iblock bblock burn $ till $ irr $ fert $ SoilC;
 label plot = 'Plot Number'
      tblock = 'Tillage Block'
      iblock = 'Irrigation Block'
      bblock = 'Burn Block'
      till = 'Tillage'
      irr = 'Irrigation'
      fert = 'Nitrogen Level'
run;

proc glm data = SoilProp;
 class tblock iblock till irr fert;
 model SoilC =
               irr
               till
               till*irr
               fert
               fert*irr
               fert*till
               fert*irr*till

               iblock
               tblock
               iblock*irr
               tblock*till
               iblock*tblock*irr*till
               iblock*tblock*fert
               iblock*tblock*irr*fert
               iblock*tblock*till*fert;
 random
               iblock
               tblock
               iblock*irr
               tblock*till
               iblock*tblock*irr*till
               iblock*tblock*fert
               iblock*tblock*irr*fert
               iblock*tblock*till*fert/ test;
quit;
```

plot	Till block	Irr block	Burn block	burn	till	irr	fert	year	C (%)	N (%)	LOI (%)	BD (g cm^{-3})	Res (kg ha^{-1})	Soy (bu/ac)
1	1	1	1	NB	CT	I	H	2011	0.92	0.11	2.31	1.29	5979	46.00
2	1	1	1	NB	NT	I	L	2011	0.78	0.09	1.93	1.29	5437	51.01
3	2	1	1	NB	NT	I	H	2011	1.00	0.11	2.35	1.27	7758	42.38
4	2	1	1	NB	CT	I	L	2011	0.94	0.10	2.29	1.26	2751	48.38
5	3	1	1	NB	NT	I	L	2011	0.67	0.08	1.87	1.32	2874	54.54
6	3	1	1	NB	CT	I	H	2011	0.96	0.11	2.64	1.35	7051	51.93
7	1	1	1	NB	CT	I	L	2011	1.07	0.12	2.48	1.28	2469	42.29
8	1	1	1	NB	NT	I	H	2011	1.00	0.11	2.19	1.23	9669	43.63
9	2	1	1	NB	NT	I	L	2011	1.11	0.13	2.87	1.20	5281	52.41
10	2	1	1	NB	CT	I	H	2011	0.94	0.11	2.35	1.28	4521	44.77
11	3	1	1	NB	NT	I	H	2011	1.22	0.13	3.30	1.21	7261	39.59
12	3	1	1	NB	CT	I	L	2011	0.76	0.10	2.04	1.31	3701	40.30
13	1	2	1	B	CT	I	L	2011	0.82	0.10	2.16	1.31	5427	64.98
14	1	2	1	B	NT	I	L	2011	0.95	0.12	2.35	1.27	4513	49.73
15	2	2	1	B	NT	I	H	2011	1.00	0.13	2.60	1.30	8943	48.44
16	2	2	1	B	CT	I	L	2011	0.98	0.13	2.57	1.23	8870	47.72
17	3	2	1	B	NT	I	H	2011	0.77	0.12	1.82	1.32	8178	50.52
18	3	2	1	B	CT	I	L	2011	1.03	0.15	2.44	1.30	5703	45.50
19	1	2	1	B	CT	I	H	2011	0.92	0.14	2.27	1.31	9808	52.41
20	1	2	1	B	NT	I	H	2011	0.89	0.10	2.15	1.33	14890	43.43
21	2	2	1	B	NT	I	L	2011	0.91	0.11	2.23	1.33	8097	46.19
22	2	2	1	B	CT	I	H	2011	0.93	0.10	2.47	1.30	6856	51.98
23	3	2	1	B	NT	I	L	2011	1.06	0.11	2.79	1.25	3038	48.60
24	3	2	1	B	CT	I	H	2011	0.87	0.10	2.28	1.33	6285	19.35
25	1	1	2	B	CT	NI	H	2011	0.77	0.09	2.14	1.39	6363	36.57
26	1	1	2	B	NT	NI	H	2011	1.14	0.12	2.56	1.29	6046	10.91
27	2	1	2	B	NT	NI	H	2011	0.89	0.10	2.12	1.32	7525	11.04
28	2	1	2	B	CT	NI	L	2011	1.10	0.12	2.47	1.29	3428	29.91
29	3	1	2	B	NT	NI	H	2011	0.89	0.10	2.20	1.32	13661	24.54
30	3	1	2	B	CT	NI	L	2011	0.88	0.10	2.25	1.32	3647	7.83
31	1	1	2	B	CT	NI	L	2011	1.05	0.12	2.43	1.31	5329	34.91
32	1	1	2	B	NT	NI	L	2011	0.98	0.10	2.47	1.29	2958	26.08
33	2	1	2	B	NT	NI	L	2011	1.14	0.12	2.85	1.24	3365	24.36
34	2	1	2	B	CT	NI	H	2011	0.86	0.10	2.32	1.33	7157	43.21
35	3	1	2	B	NT	NI	L	2011	0.95	0.11	2.38	1.26	3358	18.85
36	3	1	2	B	CT	NI	H	2011	0.85	0.10	2.16	1.29	6713	9.08
37	1	2	2	NB	CT	NI	H	2011	1.28	0.14	3.12	1.28	10060	30.90
38	1	2	2	NB	NT	NI	L	2011	1.01	0.11	2.69	1.30	3955	28.51
39	2	2	2	NB	NT	NI	H	2011	0.92	0.10	2.47	1.33	6460	27.25
40	2	2	2	NB	CT	NI	H	2011	1.21	0.13	2.99	1.25	8983	25.42
41	3	2	2	NB	NT	NI	L	2011	0.74	0.08	2.17	1.33	4018	28.32

42	3	2	2	NB	CT	NI	H	2011	0.81	0.10	2.33	1.34	9752	14.88
43	1	2	2	NB	CT	NI	L	2011	1.15	0.13	2.99	1.29	3862	32.37
44	1	2	2	NB	NT	NI	H	2011	0.96	0.11	2.66	1.29	9234	24.23
45	2	2	2	NB	NT	NI	L	2011	1.07	0.12	2.83	1.35	10013	23.07
46	2	2	2	NB	CT	NI	L	2011	1.05	0.11	2.84	1.29	4316	28.64
47	3	2	2	NB	NT	NI	H	2011	1.44	0.15	3.76	1.19	9890	19.89
48	3	2	2	NB	CT	NI	L	2011	1.11	0.12	3.11	1.31	3066	33.40
1	1	1	1	NB	CT	I	H	2012	0.89	0.10	1.80	1.33	3123	48.85
2	1	1	1	NB	NT	I	L	2012	0.98	0.11	1.89	1.26	7038	40.33
3	2	1	1	NB	NT	I	H	2012	0.99	0.10	1.95	1.26	12126	39.97
4	2	1	1	NB	CT	I	L	2012	1.11	0.12	2.15	1.24	4460	49.28
5	3	1	1	NB	NT	I	L	2012	0.81	0.09	1.72	1.32	6827	43.78
6	3	1	1	NB	CT	I	H	2012	1.04	0.12	2.13	1.24	2982	41.81
7	1	1	1	NB	CT	I	L	2012	1.23	0.12	2.15	1.23	5370	40.79
8	1	1	1	NB	NT	I	H	2012	0.90	0.10	1.74	1.29	7128	48.91
9	2	1	1	NB	NT	I	L	2012	1.07	0.11	2.18	1.25	4962	47.34
10	2	1	1	NB	CT	I	H	2012	1.12	0.12	2.27	1.26	11569	45.98
11	3	1	1	NB	NT	I	H	2012	0.98	0.11	2.10	1.22	9892	28.56
12	3	1	1	NB	CT	I	L	2012	0.94	0.10	2.16	1.37	3940	35.08
13	1	2	1	B	CT	I	L	2012	1.25	0.13	2.72	1.23	3902	28.20
14	1	2	1	B	NT	I	L	2012	0.80	0.09	1.80	1.36	4462	4.08
15	2	2	1	B	NT	I	H	2012	0.97	0.10	2.12	1.38	9135	3.89
16	2	2	1	B	CT	I	L	2012	1.04	0.11	2.13	1.30	2522	43.16
17	3	2	1	B	NT	I	H	2012	0.89	0.09	1.98	1.35	12341	32.11
18	3	2	1	B	CT	I	L	2012	1.19	0.12	2.61	1.28	2747	49.20
19	1	2	1	B	CT	I	H	2012	1.03	0.11	2.22	1.34	6704	32.93
20	1	2	1	B	NT	I	H	2012	1.06	0.11	2.25	1.27	8749	34.61
21	2	2	1	B	NT	I	L	2012	1.13	0.12	2.20	1.34	6341	40.19
22	2	2	1	B	CT	I	H	2012	0.90	0.10	2.08	1.34	8875	42.38
23	3	2	1	B	NT	I	L	2012	1.16	0.12	2.43	1.26	5622	37.45
24	3	2	1	B	CT	I	H	2012	0.91	0.10	1.98	1.29	4283	49.81
25	1	1	2	B	CT	NI	H	2012	1.45	0.15	2.87	1.25	8795	2.08
26	1	1	2	B	NT	NI	H	2012	1.09	0.11	2.17	1.30	8146	0.19
27	2	1	2	B	NT	NI	H	2012	1.21	0.12	2.28	1.26	6000	0.13
28	2	1	2	B	CT	NI	L	2012	1.00	0.11	2.28	1.29	2516	0.40
29	3	1	2	B	NT	NI	H	2012	1.01	0.11	2.17	1.29	6966	0.22
30	3	1	2	B	CT	NI	L	2012	0.82	0.09	1.85	1.31	2097	5.48
31	1	1	2	B	CT	NI	L	2012	0.99	0.11	2.36	1.29	3626	1.73
32	1	1	2	B	NT	NI	L	2012	1.02	0.11	2.07	1.31	4010	2.22
33	2	1	2	B	NT	NI	L	2012	0.94	0.10	2.18	1.28	3774	1.79
34	2	1	2	B	CT	NI	H	2012	1.21	0.13	2.82	1.25	7579	1.10
35	3	1	2	B	NT	NI	L	2012	0.93	0.10	2.23	1.25	2598	0.33
36	3	1	2	B	CT	NI	H	2012	1.11	0.12	2.47	1.26	5402	0.15

37	1	2	2	NB	CT	NI	H	2012	1.38	0.15	3.04	1.23	3468	2.13
38	1	2	2	NB	NT	NI	L	2012	1.45	0.15	2.89	1.20	3659	9.52
39	2	2	2	NB	NT	NI	H	2012	1.08	0.12	2.50	1.27	5315	5.38
40	2	2	2	NB	CT	NI	H	2012	1.33	0.14	2.77	1.24	4193	0.90
41	3	2	2	NB	NT	NI	L	2012	1.09	0.12	2.33	1.25	4138	5.59
42	3	2	2	NB	CT	NI	H	2012	1.32	0.13	2.67	1.21	3598	0.60
43	1	2	2	NB	CT	NI	L	2012	1.39	0.14	2.91	1.23	3414	0.52
44	1	2	2	NB	NT	NI	H	2012	1.15	0.12	2.64	1.28	7770	4.93
45	2	2	2	NB	NT	NI	L	2012	1.17	0.12	2.52	1.28	7645	3.75
46	2	2	2	NB	CT	NI	L	2012	1.16	0.12	2.39	1.25	2126	1.73
47	3	2	2	NB	NT	NI	H	2012	1.19	0.13	2.56	1.30	3733	4.14
48	3	2	2	NB	CT	NI	L	2012	1.15	0.12	2.50	1.28	2772	0.48

Appendix 2: Example SAS program for strip-split-split analyses and relevant data files.
(Used for season-long emissions by year and for respiration by sample date.)

```
title 'Sharon Faye Smith: ANOVA FOR ALL RESP DATA (BY DATE)';
data Resp;
 infile 'RespDaily.csv' firstobs = 2 delimiter = ",";
 input plot tblock iblock bblock burn $ till $ irr $ fert $ year doy vwc wfps temp10 temp2 flux;
    label plot = 'Plot Number'
    tblock = 'Tillage Block'
    iblock = 'Irrigation Block'
               bblock = 'Burn Block'
    till = 'Tillage'
    irr = 'Irrigation'
    fert = 'Nitrogen Level'
               year = 'Sampling Year'
               doy = 'Day of Year'
               vwc = 'Vol Water Cont (cm3/cm3)'
               wfps = 'Water Filled Pore Space (cm3/cm3 pore space)'
               temp10 = 'Temp at 10cm'
               temp2 = 'Temp at 2cm'
               flux = 'Soil Respiration (umol CO2 m-2s-1)';
run;

proc glm data = Resp; where year=2011;
 class iblock tblock irr till fert doy;
 model flux =
               irr
               till
               till*irr
               fert
               fert*irr
               fert*till
               fert*irr*till

               doy
               doy*irr
               doy*till
               doy*fert
               doy*irr*till
               doy*irr*fert
               doy*till*fert
               doy*irr*till*fert

               iblock
               tblock
               iblock*irr
               tblock*till
               iblock*tblock*irr*till
               iblock*tblock*fert
               iblock*tblock*irr*fert
```

```
                iblock*tblock*till*fert
                iblock*tblock*irr*till*fert

                iblock*doy*irr
                tblock*doy*till
                iblock*tblock*doy*fert
                iblock*tblock*doy*irr*till
                iblock*tblock*doy*irr*fert
                iblock*tblock*doy*till*fert;
 random
                iblock
                tblock
                iblock*irr
                tblock*till
                iblock*tblock*irr*till
                iblock*tblock*fert
                iblock*tblock*irr*fert
                iblock*tblock*till*fert
                iblock*tblock*irr*till*fert

                iblock*doy*irr
                tblock*doy*till
                iblock*tblock*doy*fert
                iblock*tblock*doy*irr*till
                iblock*tblock*doy*irr*fert
                iblock*tblock*doy*till*fert / test;
quit;
```

plot	tblock	iblock	bblock	burn	till	irr	fert	year	seasonCO$_2$
1	1	1	1	NB	CT	I	H	2011	3799.8
2	1	1	1	NB	NT	I	L	2011	2413.9
3	2	1	1	NB	NT	I	H	2011	2332.7
4	2	1	1	NB	CT	I	L	2011	2872.7
5	3	1	1	NB	NT	I	L	2011	1816.9
6	3	1	1	NB	CT	I	H	2011	2040.5
7	1	1	1	NB	CT	I	L	2011	2733.6
8	1	1	1	NB	NT	I	H	2011	2152.2
9	2	1	1	NB	NT	I	L	2011	1881.9
10	2	1	1	NB	CT	I	H	2011	2292.0
11	3	1	1	NB	NT	I	H	2011	1646.3
12	3	1	1	NB	CT	I	L	2011	2609.1
13	1	2	1	B	CT	I	L	2011	2114.4
14	1	2	1	B	NT	I	L	2011	2326.0
15	2	2	1	B	NT	I	H	2011	3079.9
16	2	2	1	B	CT	I	L	2011	1817.3
17	3	2	1	B	NT	I	H	2011	2389.3
18	3	2	1	B	CT	I	L	2011	1624.4
19	1	2	1	B	CT	I	H	2011	2170.1
20	1	2	1	B	NT	I	H	2011	2096.6
21	2	2	1	B	NT	I	L	2011	1605.4
22	2	2	1	B	CT	I	H	2011	1589.8
23	3	2	1	B	NT	I	L	2011	2540.8
24	3	2	1	B	CT	I	H	2011	1752.2
25	1	1	2	B	CT	NI	H	2011	2481.2
26	1	1	2	B	NT	NI	H	2011	1624.5
27	2	1	2	B	NT	NI	H	2011	1791.9
28	2	1	2	B	CT	NI	L	2011	2302.7
29	3	1	2	B	NT	NI	H	2011	2036.3
30	3	1	2	B	CT	NI	L	2011	2691.9
31	1	1	2	B	CT	NI	L	2011	2592.1
32	1	1	2	B	NT	NI	L	2011	2646.8
33	2	1	2	B	NT	NI	L	2011	2568.3
34	2	1	2	B	CT	NI	H	2011	2040.6
35	3	1	2	B	NT	NI	L	2011	1581.1
36	3	1	2	B	CT	NI	H	2011	1902.2
37	1	2	2	NB	CT	NI	H	2011	2472.1
38	1	2	2	NB	NT	NI	L	2011	1985.7
39	2	2	2	NB	NT	NI	H	2011	1488.7
40	2	2	2	NB	CT	NI	H	2011	2065.1
41	3	2	2	NB	NT	NI	L	2011	1477.2
42	3	2	2	NB	CT	NI	H	2011	2649.0

43	1	2	2	NB	CT	NI	L	2011	1889.0
44	1	2	2	NB	NT	NI	H	2011	2582.9
45	2	2	2	NB	NT	NI	L	2011	2060.1
46	2	2	2	NB	CT	NI	L	2011	2213.7
47	3	2	2	NB	NT	NI	H	2011	2654.0
48	3	2	2	NB	CT	NI	L	2011	3439.2
1	1	1	1	NB	CT	I	H	2012	2612.7
2	1	1	1	NB	NT	I	L	2012	2640.5
3	2	1	1	NB	NT	I	H	2012	2368.1
4	2	1	1	NB	CT	I	L	2012	2492.2
5	3	1	1	NB	NT	I	L	2012	1943.8
6	3	1	1	NB	CT	I	H	2012	2370.9
7	1	1	1	NB	CT	I	L	2012	1919.9
8	1	1	1	NB	NT	I	H	2012	2401.2
9	2	1	1	NB	NT	I	L	2012	2231.2
10	2	1	1	NB	CT	I	H	2012	2287.5
11	3	1	1	NB	NT	I	H	2012	1612.8
12	3	1	1	NB	CT	I	L	2012	2099.1
13	1	2	1	B	CT	I	L	2012	2563.1
14	1	2	1	B	NT	I	L	2012	1171.5
15	2	2	1	B	NT	I	H	2012	1028.3
16	2	2	1	B	CT	I	L	2012	2867.2
17	3	2	1	B	NT	I	H	2012	1885.1
18	3	2	1	B	CT	I	L	2012	2575.2
19	1	2	1	B	CT	I	H	2012	2959.0
20	1	2	1	B	NT	I	H	2012	2073.4
21	2	2	1	B	NT	I	L	2012	2393.9
22	2	2	1	B	CT	I	H	2012	2465.0
23	3	2	1	B	NT	I	L	2012	1176.9
24	3	2	1	B	CT	I	H	2012	2523.8
25	1	1	2	B	CT	NI	H	2012	833.5
26	1	1	2	B	NT	NI	H	2012	836.7
27	2	1	2	B	NT	NI	H	2012	650.5
28	2	1	2	B	CT	NI	L	2012	969.5
29	3	1	2	B	NT	NI	H	2012	760.3
30	3	1	2	B	CT	NI	L	2012	1240.8
31	1	1	2	B	CT	NI	L	2012	1164.2
32	1	1	2	B	NT	NI	L	2012	1365.7
33	2	1	2	B	NT	NI	L	2012	865.2
34	2	1	2	B	CT	NI	H	2012	1178.6
35	3	1	2	B	NT	NI	L	2012	1128.0
36	3	1	2	B	CT	NI	H	2012	748.0
37	1	2	2	NB	CT	NI	H	2012	1357.1

38	1	2	2	NB	NT	NI	L	2012	1172.9
39	2	2	2	NB	NT	NI	H	2012	1121.6
40	2	2	2	NB	CT	NI	H	2012	1259.3
41	3	2	2	NB	NT	NI	L	2012	1249.5
42	3	2	2	NB	CT	NI	H	2012	1248.2
43	1	2	2	NB	CT	NI	L	2012	2021.7
44	1	2	2	NB	NT	NI	H	2012	1371.2
45	2	2	2	NB	NT	NI	L	2012	1495.4
46	2	2	2	NB	CT	NI	L	2012	1524.1
47	3	2	2	NB	NT	NI	H	2012	1345.9
48	3	2	2	NB	CT	NI	L	2012	1153.6

plot	tblock	iblock	bblock	burn	till	irr	fert	year	doy	vwc	temp10	temp2	flux
19	1	2	1	B	CT	I	H	2011	178	0.15	29.2	28.6	3.02
22	2	2	1	B	CT	I	H	2011	178	0.196	29.1	28.1	1.67
24	3	2	1	B	CT	I	H	2011	178	0.172	29.2	28.4	3.04
1	1	1	1	NB	CT	I	H	2011	178	0.167	28.5	27.7	5.47
6	3	1	1	NB	CT	I	H	2011	178	0.187	28.5	27.8	3.59
10	2	1	1	NB	CT	I	H	2011	178	0.131	28.1	27.6	4.71
25	1	1	2	B	CT	NI	H	2011	178	0.117	29.5	28.8	3.41
34	2	1	2	B	CT	NI	H	2011	178	0.219	28.9	28.4	2.08
36	3	1	2	B	CT	NI	H	2011	178	0.126	29.4	29.6	3.24
37	1	2	2	NB	CT	NI	H	2011	178	0.235	28.2	28.6	5.42
40	2	2	2	NB	CT	NI	H	2011	178	0.236	27.7	28.4	4.24
42	3	2	2	NB	CT	NI	H	2011	178	0.169	29.1	31.1	2.62
15	2	2	1	B	NT	I	H	2011	178	0.172	29.8	27.1	1.85
17	3	2	1	B	NT	I	H	2011	178	0.187	29.7	28.8	1.98
20	1	2	1	B	NT	I	H	2011	178	0.172	29.8	29.1	1.85
3	2	1	1	NB	NT	I	H	2011	178	0.256	27.1	26.6	3.2
8	1	1	1	NB	NT	I	H	2011	178	0.246	27.0	27.1	6.98
11	3	1	1	NB	NT	I	H	2011	178	0.22	27.4	26.8	2.95
26	1	1	2	B	NT	NI	H	2011	178	0.161	29.3	29.2	1.45
27	2	1	2	B	NT	NI	H	2011	178	0.154	29.4	29.6	1.58
29	3	1	2	B	NT	NI	H	2011	178	0.191	28.8	29.2	1.78
39	2	2	2	NB	NT	NI	H	2011	178	0.223	27.7	28.2	1.96
44	1	2	2	NB	NT	NI	H	2011	178	0.127	28.5	29.1	4.89
47	3	2	2	NB	NT	NI	H	2011	178	0.228	28.2	28.2	2.94
13	1	2	1	B	CT	I	L	2011	178	0.145	29.0	28.1	5.63
16	2	2	1	B	CT	I	L	2011	178	0.155	29.3	27.4	3.62
18	3	2	1	B	CT	I	L	2011	178	0.19	29.6	29.0	3.29
4	2	1	1	NB	CT	I	L	2011	178	0.116	28.8	27.6	5.43
7	1	1	1	NB	CT	I	L	2011	178	0.181	28.6	27.6	5.19
12	3	1	1	NB	CT	I	L	2011	178	0.187	29.0	28.3	2.84
28	2	1	2	B	CT	NI	L	2011	178	0.193	28.8	29.4	1.42
30	3	1	2	B	CT	NI	L	2011	178	0.132	28.9	29.5	2.14
31	1	1	2	B	CT	NI	L	2011	178	0.086	30.1	29.9	2.43
43	1	2	2	NB	CT	NI	L	2011	178	0.121	29.9	30.7	4.37
46	2	2	2	NB	CT	NI	L	2011	178	0.177	29.7	29.6	3.76
48	3	2	2	NB	CT	NI	L	2011	178	0.145	30.0	30.4	3.83
14	1	2	1	B	NT	I	L	2011	178	0.171	29.5	28.6	1.67
21	2	2	1	B	NT	I	L	2011	178	0.204	29.8	28.9	1.57
23	3	2	1	B	NT	I	L	2011	178	0.19	29.6	28.8	1.42
2	1	1	1	NB	NT	I	L	2011	178	0.216	27.3	26.6	3.39
5	3	1	1	NB	NT	I	L	2011	178	0.208	28.4	27.6	2.24
9	2	1	1	NB	NT	I	L	2011	178	0.275	27.4	27.1	3.4

32	1	1	2	B	NT	NI	L	2011	178	0.204	29.8	29.6	1.94
33	2	1	2	B	NT	NI	L	2011	178	0.179	30.3	30.4	1.98
35	3	1	2	B	NT	NI	L	2011	178	0.206	29.8	29.8	1.56
38	1	2	2	NB	NT	NI	L	2011	178	0.268	27.7	27.7	2.16
41	3	2	2	NB	NT	NI	L	2011	178	0.235	27.9	28.2	1.27
45	2	2	2	NB	NT	NI	L	2011	178	0.208	28.8	28.9	3.22
19	1	2	1	B	CT	I	H	2011	189	0.361	30.7	35.1	12.8
22	2	2	1	B	CT	I	H	2011	189	0.446	30.8	34.3	1.28
24	3	2	1	B	CT	I	H	2011	189	0.415	30.2	34.2	7.81
1	1	1	1	NB	CT	I	H	2011	189	0.325	29.1	32.8	27.5
6	3	1	1	NB	CT	I	H	2011	189	0.367	29.9	32.9	8.87
10	2	1	1	NB	CT	I	H	2011	189	0.41	29.5	32.6	7.89
25	1	1	2	B	CT	NI	H	2011	189	0.411	30.1	33.7	10.3
34	2	1	2	B	CT	NI	H	2011	189	0.41	29.5	35.6	2.28
36	3	1	2	B	CT	NI	H	2011	189	0.29	31.2	35.2	22.2
37	1	2	2	NB	CT	NI	H	2011	189	0.405	30.6	35.2	11.8
40	2	2	2	NB	CT	NI	H	2011	189	0.378	32.0	36.1	10.7
42	3	2	2	NB	CT	NI	H	2011	189	0.339	32.1	35.4	23.1
15	2	2	1	B	NT	I	H	2011	189	0.34	29.9	33.6	14.6
17	3	2	1	B	NT	I	H	2011	189	0.335	30.8	35.1	13.2
20	1	2	1	B	NT	I	H	2011	189	0.383	31.4	35.7	9.48
3	2	1	1	NB	NT	I	H	2011	189	0.36	28.2	30.4	4.9
8	1	1	1	NB	NT	I	H	2011	189	0.375	28.8	33.3	7.46
11	3	1	1	NB	NT	I	H	2011	189	0.358	29.2	33.0	5.63
26	1	1	2	B	NT	NI	H	2011	189	0.368	31.8	35.4	8.41
27	2	1	2	B	NT	NI	H	2011	189	0.321	32.1	35.1	8.74
29	3	1	2	B	NT	NI	H	2011	189	0.387	30.7	34.8	11
39	2	2	2	NB	NT	NI	H	2011	189	0.371	30.3	35.9	5.47
44	1	2	2	NB	NT	NI	H	2011	189	0.384	31.7	35.2	24
47	3	2	2	NB	NT	NI	H	2011	189	0.378	30.8	35.6	17.6
13	1	2	1	B	CT	I	L	2011	189	0.446	29.9	32.9	11.3
16	2	2	1	B	CT	I	L	2011	189	0.448	30.3	33.9	5.1
18	3	2	1	B	CT	I	L	2011	189	0.42	30.6	34.0	4.63
4	2	1	1	NB	CT	I	L	2011	189	0.351	29.9	33.1	24.6
7	1	1	1	NB	CT	I	L	2011	189	0.383	29.7	33.3	16.9
12	3	1	1	NB	CT	I	L	2011	189	0.383	29.6	33.0	10.2
28	2	1	2	B	CT	NI	L	2011	189	0.382	31.9	35.9	20.9
30	3	1	2	B	CT	NI	L	2011	189	0.295	30.8	34.7	31.3
31	1	1	2	B	CT	NI	L	2011	189	0.342	30.5	35.9	21.5
43	1	2	2	NB	CT	NI	L	2011	189	0.373	30.8	35.8	9.36
46	2	2	2	NB	CT	NI	L	2011	189	0.366	31.2	35.8	11
48	3	2	2	NB	CT	NI	L	2011	189	0.36	31.9	36.3	40.7
14	1	2	1	B	NT	I	L	2011	189	0.294	29.9	33.2	10.7

21	2	2	1	B	NT	I	L	2011	189	0.392	31.4	35.2	5.48
23	3	2	1	B	NT	I	L	2011	189	0.351	30.7	34.7	23.1
2	1	1	1	NB	NT	I	L	2011	189	0.354	27.8	31.6	3.9
5	3	1	1	NB	NT	I	L	2011	189	0.36	29.5	32.1	8.88
9	2	1	1	NB	NT	I	L	2011	189	0.368	28.5	32.3	6.73
32	1	1	2	B	NT	NI	L	2011	189	0.364	31.0	37.5	7.05
33	2	1	2	B	NT	NI	L	2011	189	0.345	31.1	36.1	28.1
35	3	1	2	B	NT	NI	L	2011	189	0.348	31.1	35.2	14.7
38	1	2	2	NB	NT	NI	L	2011	189	0.383	30.5	35.3	10.1
41	3	2	2	NB	NT	NI	L	2011	189	0.399	31.5	36.2	5.22
45	2	2	2	NB	NT	NI	L	2011	189	0.369	31.1	34.6	11.2
19	1	2	1	B	CT	I	H	2011	201	0.154	29.9	28.3	3.88
22	2	2	1	B	CT	I	H	2011	201	0.119	29.5	28.1	4.41
24	3	2	1	B	CT	I	H	2011	201	0.159	29.9	29.1	2.13
1	1	1	1	NB	CT	I	H	2011	201	0.231	28.6	28.1	7.12
6	3	1	1	NB	CT	I	H	2011	201	0.084	28.7	29.7	4.87
10	2	1	1	NB	CT	I	H	2011	201	0.117	29.2	28.7	4.53
25	1	1	2	B	CT	NI	H	2011	201	0.095	29.8	28.2	4.88
34	2	1	2	B	CT	NI	H	2011	201	0.115	29.6	27.8	4.05
36	3	1	2	B	CT	NI	H	2011	201	0.128	30.1	28.3	1.56
37	1	2	2	NB	CT	NI	H	2011	201	0.161	29.2	27.9	3.8
40	2	2	2	NB	CT	NI	H	2011	201	0.222	28.6	28.1	2.96
42	3	2	2	NB	CT	NI	H	2011	201	0.144	30.1	28.7	3.36
15	2	2	1	B	NT	I	H	2011	201	0.209	29.4	28.8	3.27
17	3	2	1	B	NT	I	H	2011	201	0.126	29.2	29.0	4.05
20	1	2	1	B	NT	I	H	2011	201	0.127	30.0	28.7	4.12
3	2	1	1	NB	NT	I	H	2011	201	0.104	27.7	28.2	6.28
8	1	1	1	NB	NT	I	H	2011	201	0.192	28.3	27.9	3.77
11	3	1	1	NB	NT	I	H	2011	201	0.166	27.9	27.6	3.81
26	1	1	2	B	NT	NI	H	2011	201	0.108	29.6	28.4	3.68
27	2	1	2	B	NT	NI	H	2011	201	0.212	29.6	28.8	2.27
29	3	1	2	B	NT	NI	H	2011	201	0.094	29.4	28.9	3.61
39	2	2	2	NB	NT	NI	H	2011	201	0.153	28.3	27.3	2.81
44	1	2	2	NB	NT	NI	H	2011	201	0.134	27.7	26.7	3.15
47	3	2	2	NB	NT	NI	H	2011	201	0.103	28.4	26.4	5.82
13	1	2	1	B	CT	I	L	2011	201	0.194	29.2	28.4	2.74
16	2	2	1	B	CT	I	L	2011	201	0.202	29.3	28.9	1.96
18	3	2	1	B	CT	I	L	2011	201	0.126	29.7	29.3	2.55
4	2	1	1	NB	CT	I	L	2011	201	0.095	28.2	28.7	4.1
7	1	1	1	NB	CT	I	L	2011	201	0.089	29.3	28.9	4.46
12	3	1	1	NB	CT	I	L	2011	201	0.089	29.4	28.8	5.18
28	2	1	2	B	CT	NI	L	2011	201	0.101	29.2	28.4	4.64
30	3	1	2	B	CT	NI	L	2011	201	0.153	29.3	29.3	1.95

31	1	1	2	B	CT	NI	L	2011	201	0.097	29.9	28.4	2.76
43	1	2	2	NB	CT	NI	L	2011	201	0.2	29.3	27.7	3.13
46	2	2	2	NB	CT	NI	L	2011	201	0.153	29.3	27.8	3.13
48	3	2	2	NB	CT	NI	L	2011	201	0.134	29.8	27.9	3.29
14	1	2	1	B	NT	I	L	2011	201	0.167	28.9	28.4	4.77
21	2	2	1	B	NT	I	L	2011	201	0.145	30.0	28.9	2.04
23	3	2	1	B	NT	I	L	2011	201	0.11	29.3	29.1	2.97
2	1	1	1	NB	NT	I	L	2011	201	0.122	28.0	27.9	7.73
5	3	1	1	NB	NT	I	L	2011	201	0.104	28.2	28.9	4.45
9	2	1	1	NB	NT	I	L	2011	201	0.119	28.3	28.8	4.78
32	1	1	2	B	NT	NI	L	2011	201	0.134	29.8	27.9	5.54
33	2	1	2	B	NT	NI	L	2011	201	0.065	30.1	28.7	2.9
35	3	1	2	B	NT	NI	L	2011	201	0.171	29.9	28.4	1.48
38	1	2	2	NB	NT	NI	L	2011	201	0.11	27.7	26.9	4.22
41	3	2	2	NB	NT	NI	L	2011	201	0.186	28.5	27.4	1.76
45	2	2	2	NB	NT	NI	L	2011	201	0.156	28.4	27.1	3.86
19	1	2	1	B	CT	I	H	2011	212	0.303	28.5	32.6	5.62
22	2	2	1	B	CT	I	H	2011	212	0.377	28.0	32.8	6.1
24	3	2	1	B	CT	I	H	2011	212	0.287	30.0	36.3	6.51
1	1	1	1	NB	CT	I	H	2011	212	0.322	28.1	32.4	9.66
6	3	1	1	NB	CT	I	H	2011	212	0.327	28.0	30.6	7.04
10	2	1	1	NB	CT	I	H	2011	212	0.265	28.1	31.2	9.12
25	1	1	2	B	CT	NI	H	2011	212	0.266	31.3	35.3	13
34	2	1	2	B	CT	NI	H	2011	212	0.304	31.5	36.8	10.8
36	3	1	2	B	CT	NI	H	2011	212	0.205	34.2	41.4	4.23
37	1	2	2	NB	CT	NI	H	2011	212	0.332	30.8	34.9	6.09
40	2	2	2	NB	CT	NI	H	2011	212	0.322	32.3	37.8	7.54
42	3	2	2	NB	CT	NI	H	2011	212	0.261	32.8	37.4	9.33
15	2	2	1	B	NT	I	H	2011	212	0.284	29.3	33.7	17.9
17	3	2	1	B	NT	I	H	2011	212	0.341	29.1	31.8	10.8
20	1	2	1	B	NT	I	H	2011	212	0.302	28.7	31.8	9.62
3	2	1	1	NB	NT	I	H	2011	212	0.254	27.6	29.7	11.2
8	1	1	1	NB	NT	I	H	2011	212	0.302	27.6	30.6	6.13
11	3	1	1	NB	NT	I	H	2011	212	0.29	28.1	30.7	5.47
26	1	1	2	B	NT	NI	H	2011	212	0.286	31.7	35.2	5.59
27	2	1	2	B	NT	NI	H	2011	212	0.248	33.7	39.9	5.28
29	3	1	2	B	NT	NI	H	2011	212	0.265	31.0	36.2	7.88
39	2	2	2	NB	NT	NI	H	2011	212	0.271	31.2	33.4	4.56
44	1	2	2	NB	NT	NI	H	2011	212	0.321	30.3	34.0	5.28
47	3	2	2	NB	NT	NI	H	2011	212	0.249	31.1	34.3	11.6
13	1	2	1	B	CT	I	L	2011	212	0.368	29.0	32.3	5.46
16	2	2	1	B	CT	I	L	2011	212	0.345	29.6	35.0	2.26
18	3	2	1	B	CT	I	L	2011	212	0.319	28.2	32.2	5.29

4	2	1	1	NB	CT	I	L	2011	212	0.294	28.7	32.3	6.27
7	1	1	1	NB	CT	I	L	2011	212	0.271	28.1	30.8	7.62
12	3	1	1	NB	CT	I	L	2011	212	0.281	28.3	31.7	11.5
28	2	1	2	B	CT	NI	L	2011	212	0.195	32.4	39.9	7.41
30	3	1	2	B	CT	NI	L	2011	212	0.219	34.5	42.8	4.09
31	1	1	2	B	CT	NI	L	2011	212	0.23	33.2	37.6	9.36
43	1	2	2	NB	CT	NI	L	2011	212	0.294	32.8	35.2	6.07
46	2	2	2	NB	CT	NI	L	2011	212	0.327	30.9	35.8	8.37
48	3	2	2	NB	CT	NI	L	2011	212	0.248	34.7	39.4	7.41
14	1	2	1	B	NT	I	L	2011	212	0.239	28.4	31.5	12.4
21	2	2	1	B	NT	I	L	2011	212	0.309	28.6	31.7	7.59
23	3	2	1	B	NT	I	L	2011	212	0.295	28.7	31.5	6.86
2	1	1	1	NB	NT	I	L	2011	212	0.267	28.3	30.2	14.1
5	3	1	1	NB	NT	I	L	2011	212	0.288	27.8	30.1	5.54
9	2	1	1	NB	NT	I	L	2011	212	0.255	27.8	31.3	4.78
32	1	1	2	B	NT	NI	L	2011	212	0.266	31.0	35.2	17.9
33	2	1	2	B	NT	NI	L	2011	212	0.278	32.0	38.3	8.15
35	3	1	2	B	NT	NI	L	2011	212	0.24	35.5	42.2	4.14
38	1	2	2	NB	NT	NI	L	2011	212	0.354	30.5	36.9	7.58
41	3	2	2	NB	NT	NI	L	2011	212	0.329	31.4	36.3	5.95
45	2	2	2	NB	NT	NI	L	2011	212	0.309	30.5	34.2	9
19	1	2	1	B	CT	I	H	2011	230	0.306	24.3	24.3	5.27
22	2	2	1	B	CT	I	H	2011	230	0.338	24.3	24.3	5.63
24	3	2	1	B	CT	I	H	2011	230	0.219	25.3	24.9	6.15
1	1	1	1	NB	CT	I	H	2011	230	0.292	25.1	24.6	10.3
6	3	1	1	NB	CT	I	H	2011	230	0.274	24.2	24.6	5.89
10	2	1	1	NB	CT	I	H	2011	230	0.249	24.3	24.0	6.12
25	1	1	2	B	CT	NI	H	2011	230	0.094	26.3	23.9	6.61
34	2	1	2	B	CT	NI	H	2011	230	0.114	26.1	24.6	5.7
36	3	1	2	B	CT	NI	H	2011	230	0.17	27.9	25.5	2.37
37	1	2	2	NB	CT	NI	H	2011	230	0.132	26.2	25.1	4.31
40	2	2	2	NB	CT	NI	H	2011	230	0.119	26.5	25.2	4.04
42	3	2	2	NB	CT	NI	H	2011	230	0.165	27.2	25.6	3.21
15	2	2	1	B	NT	I	H	2011	230	0.231	24.5	24.5	9.52
17	3	2	1	B	NT	I	H	2011	230	0.263	24.6	24.3	8.08
20	1	2	1	B	NT	I	H	2011	230	0.254	24.5	24.5	7.35
3	2	1	1	NB	NT	I	H	2011	230	0.11	24.4	24.6	9.14
8	1	1	1	NB	NT	I	H	2011	230	0.261	24.6	24.0	5.07
11	3	1	1	NB	NT	I	H	2011	230	0.201	24.4	24.6	4.32
26	1	1	2	B	NT	NI	H	2011	230	0.125	27.4	24.9	4.06
27	2	1	2	B	NT	NI	H	2011	230	0.164	26.8	24.0	2.81
29	3	1	2	B	NT	NI	H	2011	230	0.106	26.9	25.3	4.83
39	2	2	2	NB	NT	NI	H	2011	230	0.118	25.6	24.8	3.22

44	1	2	2	NB	NT	NI	H	2011	230	0.094	26.0	25.0	3.46
47	3	2	2	NB	NT	NI	H	2011	230	0.104	26.1	25.1	5.58
13	1	2	1	B	CT	I	L	2011	230	0.333	24.3	23.9	4.6
16	2	2	1	B	CT	I	L	2011	230	0.301	24.4	24.3	4.43
18	3	2	1	B	CT	I	L	2011	230	0.315	24.2	24.0	5.57
4	2	1	1	NB	CT	I	L	2011	230	0.284	24.0	24.6	5.93
7	1	1	1	NB	CT	I	L	2011	230	0.268	24.4	24.1	5.7
12	3	1	1	NB	CT	I	L	2011	230	0.128	24.3	24.6	9.72
28	2	1	2	B	CT	NI	L	2011	230	0.118	26.9	24.2	4.36
30	3	1	2	B	CT	NI	L	2011	230	0.189	27.8	24.7	1.97
31	1	1	2	B	CT	NI	L	2011	230	0.109	26.6	25.3	4.8
43	1	2	2	NB	CT	NI	L	2011	230	0.151	25.8	26.0	3.87
46	2	2	2	NB	CT	NI	L	2011	230	0.151	26.3	24.7	3.87
48	3	2	2	NB	CT	NI	L	2011	230	0.113	26.7	25.1	4.24
14	1	2	1	B	NT	I	L	2011	230	0.257	24.4	24.2	8.24
21	2	2	1	B	NT	I	L	2011	230	0.254	24.5	24.6	5.87
23	3	2	1	B	NT	I	L	2011	230	0.219	24.6	24.4	6.9
2	1	1	1	NB	NT	I	L	2011	230	0.135	24.5	24.6	9
5	3	1	1	NB	NT	I	L	2011	230	0.272	24.2	24.6	5.39
9	2	1	1	NB	NT	I	L	2011	230	0.254	24.5	24.0	5.08
32	1	1	2	B	NT	NI	L	2011	230	0.107	26.5	24.3	8.32
33	2	1	2	B	NT	NI	L	2011	230	0.074	26.9	24.7	4.17
35	3	1	2	B	NT	NI	L	2011	230	0.137	26.3	24.7	2.11
38	1	2	2	NB	NT	NI	L	2011	230	0.103	25.9	24.7	5.3
41	3	2	2	NB	NT	NI	L	2011	230	0.014	26.0	24.8	3.42
45	2	2	2	NB	NT	NI	L	2011	230	0.139	25.8	25.3	3.78
19	1	2	1	B	CT	I	H	2011	246	0.367	27.8	26.5	3.63
22	2	2	1	B	CT	I	H	2011	246	0.406	28.2	26.1	2.13
24	3	2	1	B	CT	I	H	2011	246	0.307	29.9	29.6	1.4
1	1	1	1	NB	CT	I	H	2011	246	0.371	29.6	26.7	3.92
6	3	1	1	NB	CT	I	H	2011	246	0.328	26.5	26.3	2.61
10	2	1	1	NB	CT	I	H	2011	246	0.304	27.3	26.1	3.58
25	1	1	2	B	CT	NI	H	2011	246	0.078	28.0	29.9	4.2
34	2	1	2	B	CT	NI	H	2011	246	0.087	25.2	28.3	8.16
36	3	1	2	B	CT	NI	H	2011	246	0.06	26.0	32.0	2.08
37	1	2	2	NB	CT	NI	H	2011	246	0.106	25.7	27.8	11
40	2	2	2	NB	CT	NI	H	2011	246	0.11	25.7	28.1	4.76
42	3	2	2	NB	CT	NI	H	2011	246	0.074	25.7	30.3	5.61
15	2	2	1	B	NT	I	H	2011	246	0.323	26.7	26.6	4.34
17	3	2	1	B	NT	I	H	2011	246	0.371	28.2	26.8	3.17
20	1	2	1	B	NT	I	H	2011	246	0.344	29.2	26.2	1.49
3	2	1	1	NB	NT	I	H	2011	246	0.235	26.8	26.3	3.46
8	1	1	1	NB	NT	I	H	2011	246	0.27	26.5	26.4	2.65

11	3	1	1	NB	NT	I	H	2011	246	0.107	27.5	26.2	3.73
26	1	1	2	B	NT	NI	H	2011	246	0.023	25.6	31.3	5.16
27	2	1	2	B	NT	NI	H	2011	246	0.057	25.2	34.6	9.75
29	3	1	2	B	NT	NI	H	2011	246	0.022	25.6	33.8	6.51
39	2	2	2	NB	NT	NI	H	2011	246	0.129	25.4	28.0	6.3
44	1	2	2	NB	NT	NI	H	2011	246	0.103	25.4	27.4	6.47
47	3	2	2	NB	NT	NI	H	2011	246	0.095	25.5	26.9	4.52
13	1	2	1	B	CT	I	L	2011	246	0.348	29.5	26.6	1.6
16	2	2	1	B	CT	I	L	2011	246	0.379	27.8	26.2	6.66
18	3	2	1	B	CT	I	L	2011	246	0.362	27.6	26.7	3.87
4	2	1	1	NB	CT	I	L	2011	246	0.305	26.1	26.7	2.66
7	1	1	1	NB	CT	I	L	2011	246	0.359	26.4	26.3	3.64
12	3	1	1	NB	CT	I	L	2011	246	0.329	29.1	26.4	1.29
28	2	1	2	B	CT	NI	L	2011	246	0.077	25.1	31.4	4.71
30	3	1	2	B	CT	NI	L	2011	246	0.099	25.4	32.4	11.1
31	1	1	2	B	CT	NI	L	2011	246	0.058	25.5	29.6	5.5
43	1	2	2	NB	CT	NI	L	2011	246	0.152	26.1	37.2	4.12
46	2	2	2	NB	CT	NI	L	2011	246	0.078	25.7	28.0	6.86
48	3	2	2	NB	CT	NI	L	2011	246	0.106	25.5	28.3	7.07
14	1	2	1	B	NT	I	L	2011	246	0.284	28.6	25.4	1.83
21	2	2	1	B	NT	I	L	2011	246	0.406	29.7	26.3	2.37
23	3	2	1	B	NT	I	L	2011	246	0.344	28.6	26.6	2.91
2	1	1	1	NB	NT	I	L	2011	246	0.288	26.4	26.1	2.11
5	3	1	1	NB	NT	I	L	2011	246	0.259	26.3	26.1	2.44
9	2	1	1	NB	NT	I	L	2011	246	0.272	26.7	25.9	3.12
32	1	1	2	B	NT	NI	L	2011	246	0.032	25.8	30.1	4.22
33	2	1	2	B	NT	NI	L	2011	246	0.034	25.9	29.8	3.59
35	3	1	2	B	NT	NI	L	2011	246	0.06	25.9	31.4	4.08
38	1	2	2	NB	NT	NI	L	2011	246	0.119	26.0	27.5	5.3
41	3	2	2	NB	NT	NI	L	2011	246	0.023	25.5	27.4	6.15
45	2	2	2	NB	NT	NI	L	2011	246	0.115	25.5	26.8	4.71
19	1	2	1	B	CT	I	H	2011	260	0.315	18.4	18.9	4.34
22	2	2	1	B	CT	I	H	2011	260	0.395	18.4	19.4	3.73
24	3	2	1	B	CT	I	H	2011	260	0.35	19.3	20.7	2.13
1	1	1	1	NB	CT	I	H	2011	260	0.328	19.5	20.5	4.14
6	3	1	1	NB	CT	I	H	2011	260	0.316	19.4	20.8	2.73
10	2	1	1	NB	CT	I	H	2011	260	0.311	18.9	19.8	3
25	1	1	2	B	CT	NI	H	2011	260	0.071	20.8	21.8	1.05
34	2	1	2	B	CT	NI	H	2011	260	0.095	20.2	21.2	1.12
36	3	1	2	B	CT	NI	H	2011	260	0.06	21.0	22.8	0.737
37	1	2	2	NB	CT	NI	H	2011	260	0.075	20.5	20.9	1.05
40	2	2	2	NB	CT	NI	H	2011	260	0.089	20.8	21.9	1.11
42	3	2	2	NB	CT	NI	H	2011	260	0.097	21.0	22.6	0.525

15	2	2	1	B	NT	I	H	2011	260	0.27	18.4	20.0	2.04
17	3	2	1	B	NT	I	H	2011	260	0.307	18.7	20.3	1.92
20	1	2	1	B	NT	I	H	2011	260	0.29	18.7	19.3	3.23
3	2	1	1	NB	NT	I	H	2011	260	0.255	19.8	20.9	2.41
8	1	1	1	NB	NT	I	H	2011	260	0.24	19.5	20.6	3.15
11	3	1	1	NB	NT	I	H	2011	260	0.072	20.3	20.9	1.96
26	1	1	2	B	NT	NI	H	2011	260	0.023	21.2	22.0	0.668
27	2	1	2	B	NT	NI	H	2011	260	0.067	21.6	23.4	0.935
29	3	1	2	B	NT	NI	H	2011	260	0.061	21.6	23.1	1.25
39	2	2	2	NB	NT	NI	H	2011	260	0.071	20.4	21.1	1.09
44	1	2	2	NB	NT	NI	H	2011	260	0.072	20.3	20.9	0.814
47	3	2	2	NB	NT	NI	H	2011	260	0.045	20.3	20.3	0.74
13	1	2	1	B	CT	I	L	2011	260	0.343	18.6	19.6	4.01
16	2	2	1	B	CT	I	L	2011	260	0.363	18.6	19.2	5.32
18	3	2	1	B	CT	I	L	2011	260	0.362	18.5	19.6	1.33
4	2	1	1	NB	CT	I	L	2011	260	0.306	19.1	20.2	3.04
7	1	1	1	NB	CT	I	L	2011	260	0.329	18.7	19.4	3.39
12	3	1	1	NB	CT	I	L	2011	260	0.251	18.7	19.9	4.54
28	2	1	2	B	CT	NI	L	2011	260	0.074	21.1	23.0	0.87
30	3	1	2	B	CT	NI	L	2011	260	0.081	22.0	23.5	0.579
31	1	1	2	B	CT	NI	L	2011	260	0.08	20.6	21.3	1.24
43	1	2	2	NB	CT	NI	L	2011	260	0.094	19.9	20.4	0.94
46	2	2	2	NB	CT	NI	L	2011	260	0.061	20.5	20.5	1.3
48	3	2	2	NB	CT	NI	L	2011	260	0.086	21.2	20.6	1.14
14	1	2	1	B	NT	I	L	2011	260	0.344	18.5	19.2	2
21	2	2	1	B	NT	I	L	2011	260	0.336	18.8	19.2	2.6
23	3	2	1	B	NT	I	L	2011	260	0.302	18.5	19.2	2.91
2	1	1	1	NB	NT	I	L	2011	260	0.301	19.6	20.7	1.51
5	3	1	1	NB	NT	I	L	2011	260	0.272	19.1	20.4	2.14
9	2	1	1	NB	NT	I	L	2011	260	0.294	19.5	20.4	3.01
32	1	1	2	B	NT	NI	L	2011	260	0.055	20.9	21.9	1.13
33	2	1	2	B	NT	NI	L	2011	260	0.075	21.1	21.8	1.3
35	3	1	2	B	NT	NI	L	2011	260	0.065	21.2	22.6	0.696
38	1	2	2	NB	NT	NI	L	2011	260	0.059	20.7	21.4	0.892
41	3	2	2	NB	NT	NI	L	2011	260	0.097	21.0	21.5	1.27
45	2	2	2	NB	NT	NI	L	2011	260	0.099	20.4	21.1	0.873
19	1	2	1	B	CT	I	H	2011	274	0.311	16.8	15.0	1.17
22	2	2	1	B	CT	I	H	2011	274	0.326	16.5	15.2	2.49
24	3	2	1	B	CT	I	H	2011	274	0.298	15.5	15.9	1.48
1	1	1	1	NB	CT	I	H	2011	274	0.326	16.8	17.6	2.82
6	3	1	1	NB	CT	I	H	2011	274	0.316	16.7	16.2	1.15
10	2	1	1	NB	CT	I	H	2011	274	0.333	16.4	16.4	1.56
25	1	1	2	B	CT	NI	H	2011	274	0.283	17.1	14.4	1.53

34	2	1	2	B	CT	NI	H	2011	274	0.291	16.4	14.0	1.51
36	3	1	2	B	CT	NI	H	2011	274	0.126	16.9	12.4	0.905
37	1	2	2	NB	CT	NI	H	2011	274	0.268	17.8	13.3	1.13
40	2	2	2	NB	CT	NI	H	2011	274	0.245	16.6	13.9	1.67
42	3	2	2	NB	CT	NI	H	2011	274	0.165	18.2	13.8	1.88
15	2	2	1	B	NT	I	H	2011	274	0.3	16.8	14.8	2.28
17	3	2	1	B	NT	I	H	2011	274	0.313	16.2	14.8	1.15
20	1	2	1	B	NT	I	H	2011	274	0.322	16.7	15.2	1.21
3	2	1	1	NB	NT	I	H	2011	274	0.244	17.8	17.0	0.864
8	1	1	1	NB	NT	I	H	2011	274	0.337	17.6	17.3	1.82
11	3	1	1	NB	NT	I	H	2011	274	0.273	17.0	16.1	1.36
26	1	1	2	B	NT	NI	H	2011	274	0.242	17.5	14.8	1.13
27	2	1	2	B	NT	NI	H	2011	274	0.247	16.8	13.5	1.46
29	3	1	2	B	NT	NI	H	2011	274	0.28	17.2	13.3	1.07
39	2	2	2	NB	NT	NI	H	2011	274	0.256	18.7	13.2	1.17
44	1	2	2	NB	NT	NI	H	2011	274	0.275	18.6	14.4	1.23
47	3	2	2	NB	NT	NI	H	2011	274	0.23	18.1	13.4	1.37
13	1	2	1	B	CT	I	L	2011	274	0.332	16.4	14.4	2.18
16	2	2	1	B	CT	I	L	2011	274	0.292	17.2	15.6	2.08
18	3	2	1	B	CT	I	L	2011	274	0.305	16.5	15.2	1.37
4	2	1	1	NB	CT	I	L	2011	274	0.288	16.3	15.9	1.98
7	1	1	1	NB	CT	I	L	2011	274	0.317	16.7	18.0	2.89
12	3	1	1	NB	CT	I	L	2011	274	0.238	16.3	15.5	1.66
28	2	1	2	B	CT	NI	L	2011	274	0.268	15.6	12.9	0.95
30	3	1	2	B	CT	NI	L	2011	274	0.199	17.1	13.8	0.678
31	1	1	2	B	CT	NI	L	2011	274	0.269	16.1	14.8	1.9
43	1	2	2	NB	CT	NI	L	2011	274	0.223	17.4	13.1	1.68
46	2	2	2	NB	CT	NI	L	2011	274	0.265	17.6	13.2	1.62
48	3	2	2	NB	CT	NI	L	2011	274	0.159	16.4	10.6	0.822
14	1	2	1	B	NT	I	L	2011	274	0.276	17.3	15.3	1.07
21	2	2	1	B	NT	I	L	2011	274	0.307	16.9	15.4	0.849
23	3	2	1	B	NT	I	L	2011	274	0.253	16.0	14.7	1.82
2	1	1	1	NB	NT	I	L	2011	274	0.282	17.6	18.1	1.05
5	3	1	1	NB	NT	I	L	2011	274	0.28	16.8	15.8	1.54
9	2	1	1	NB	NT	I	L	2011	274	0.255	17.3	17.2	2.09
32	1	1	2	B	NT	NI	L	2011	274	0.247	17.1	13.8	1.59
33	2	1	2	B	NT	NI	L	2011	274	0.269	16.7	13.9	0.893
35	3	1	2	B	NT	NI	L	2011	274	0.233	17.5	14.2	1.49
38	1	2	2	NB	NT	NI	L	2011	274	0.312	17.4	14.2	0.928
41	3	2	2	NB	NT	NI	L	2011	274	0.284	17.1	14.4	1.23
45	2	2	2	NB	NT	NI	L	2011	274	0.275	17.7	14.4	1.14
19	1	2	1	B	CT	I	H	2011	288	0.305	16.8	16.9	1.94
22	2	2	1	B	CT	I	H	2011	288	0.308	16.8	16.4	1.89

24	3	2	1	B	CT	I	H	2011	288	0.219	16.7	14.4	1.87
1	1	1	1	NB	CT	I	H	2011	288	0.304	16.4	16.7	2.59
6	3	1	1	NB	CT	I	H	2011	288	0.231	17.5	17.6	1.45
10	2	1	1	NB	CT	I	H	2011	288	0.29	16.3	17.1	1.6
25	1	1	2	B	CT	NI	H	2011	288	0.283	16.7	14.5	1.29
34	2	1	2	B	CT	NI	H	2011	288	0.202	16.0	14.7	1.19
36	3	1	2	B	CT	NI	H	2011	288	0.172	15.9	14.1	0.904
37	1	2	2	NB	CT	NI	H	2011	288	0.218	17.5	14.8	0.898
40	2	2	2	NB	CT	NI	H	2011	288	0.276	17.1	15.0	1.68
42	3	2	2	NB	CT	NI	H	2011	288	0.219	17.3	14.4	3.75
15	2	2	1	B	NT	I	H	2011	288	0.284	16.7	17.5	2.4
17	3	2	1	B	NT	I	H	2011	288	0.326	16.0	15.4	0.78
20	1	2	1	B	NT	I	H	2011	288	0.273	16.3	18.0	1.12
3	2	1	1	NB	NT	I	H	2011	288	0.254	17.2	18.1	0.793
8	1	1	1	NB	NT	I	H	2011	288	0.307	16.7	16.8	1.83
11	3	1	1	NB	NT	I	H	2011	288	0.237	16.7	17.7	1.31
26	1	1	2	B	NT	NI	H	2011	288	0.262	16.4	14.7	0.817
27	2	1	2	B	NT	NI	H	2011	288	0.252	16.6	13.8	1.09
29	3	1	2	B	NT	NI	H	2011	288	0.204	16.4	14.6	0.713
39	2	2	2	NB	NT	NI	H	2011	288	0.275	17.6	15.6	1.24
44	1	2	2	NB	NT	NI	H	2011	288	0.269	17.7	15.3	1.2
47	3	2	2	NB	NT	NI	H	2011	288	0.223	17.0	15.0	1.23
13	1	2	1	B	CT	I	L	2011	288	0.303	16.0	17.4	1.88
16	2	2	1	B	CT	I	L	2011	288	0.318	17.4	16.6	1.63
18	3	2	1	B	CT	I	L	2011	288	0.294	17.1	15.3	1.48
4	2	1	1	NB	CT	I	L	2011	288	0.27	16.4	17.7	1.98
7	1	1	1	NB	CT	I	L	2011	288	0.274	17.2	16.2	2.48
12	3	1	1	NB	CT	I	L	2011	288	0.274	17.6	17.2	1.77
28	2	1	2	B	CT	NI	L	2011	288	0.275	15.9	13.8	0.735
30	3	1	2	B	CT	NI	L	2011	288	0.268	16.2	15.0	0.789
31	1	1	2	B	CT	NI	L	2011	288	0.26	16.8	14.5	1.3
43	1	2	2	NB	CT	NI	L	2011	288	0.235	17.1	14.7	1.75
46	2	2	2	NB	CT	NI	L	2011	288	0.302	17.1	14.4	1.73
48	3	2	2	NB	CT	NI	L	2011	288	0.177	15.8	13.7	1.23
14	1	2	1	B	NT	I	L	2011	288	0.301	17.2	16.8	1.23
21	2	2	1	B	NT	I	L	2011	288	0.289	16.4	16.4	1.28
23	3	2	1	B	NT	I	L	2011	288	0.249	15.8	15.0	1.58
2	1	1	1	NB	NT	I	L	2011	288	0.256	17.3	18.1	1.13
5	3	1	1	NB	NT	I	L	2011	288	0.227	16.7	17.9	2.32
9	2	1	1	NB	NT	I	L	2011	288	0.246	16.9	17.4	2.5
32	1	1	2	B	NT	NI	L	2011	288	0.256	17.0	14.5	1.25
33	2	1	2	B	NT	NI	L	2011	288	0.253	16.2	14.4	0.761
35	3	1	2	B	NT	NI	L	2011	288	0.279	16.7	15.3	1.3

38	1	2	2	NB	NT	NI	L	2011	288	0.273	17.3	14.8	1.17
41	3	2	2	NB	NT	NI	L	2011	288	0.282	17.5	15.6	1.32
45	2	2	2	NB	NT	NI	L	2011	288	0.272	17.6	14.7	1.37
19	1	2	1	B	CT	I	H	2012	159	0.311	16.8	15.0	1.17
22	2	2	1	B	CT	I	H	2012	159	0.326	16.5	15.2	2.49
24	3	2	1	B	CT	I	H	2012	159	0.298	15.5	15.9	1.48
1	1	1	1	NB	CT	I	H	2012	159	0.326	16.8	17.6	2.82
6	3	1	1	NB	CT	I	H	2012	159	0.316	16.7	16.2	1.15
10	2	1	1	NB	CT	I	H	2012	159	0.333	16.5	16.4	1.56
25	1	1	2	B	CT	NI	H	2012	159	0.283	17.0	14.4	1.53
34	2	1	2	B	CT	NI	H	2012	159	0.291	16.4	14.0	1.51
36	3	1	2	B	CT	NI	H	2012	159	0.126	17.0	12.4	0.905
37	1	2	2	NB	CT	NI	H	2012	159	0.268	17.7	13.3	1.13
40	2	2	2	NB	CT	NI	H	2012	159	0.245	16.6	13.9	1.67
42	3	2	2	NB	CT	NI	H	2012	159	0.165	18.2	13.8	1.88
15	2	2	1	B	NT	I	H	2012	159	0.3	16.9	14.8	2.28
17	3	2	1	B	NT	I	H	2012	159	0.313	16.2	14.8	1.15
20	1	2	1	B	NT	I	H	2012	159	0.322	16.7	15.2	1.21
3	2	1	1	NB	NT	I	H	2012	159	0.244	17.8	17.0	0.864
8	1	1	1	NB	NT	I	H	2012	159	0.337	17.2	17.3	1.83
11	3	1	1	NB	NT	I	H	2012	159	0.273	17.0	16.1	1.36
26	1	1	2	B	NT	NI	H	2012	159	0.242	17.5	14.8	1.13
27	2	1	2	B	NT	NI	H	2012	159	0.247	16.7	13.5	1.46
29	3	1	2	B	NT	NI	H	2012	159	0.28	17.2	13.3	1.07
39	2	2	2	NB	NT	NI	H	2012	159	0.256	17.6	13.2	1.14
44	1	2	2	NB	NT	NI	H	2012	159	0.275	18.7	14.4	1.28
47	3	2	2	NB	NT	NI	H	2012	159	0.23	18.0	13.4	1.37
13	1	2	1	B	CT	I	L	2012	159	0.332	16.5	14.4	2.18
16	2	2	1	B	CT	I	L	2012	159	0.292	17.2	15.6	2.05
18	3	2	1	B	CT	I	L	2012	159	0.305	16.5	15.2	1.37
4	2	1	1	NB	CT	I	L	2012	159	0.288	16.3	15.9	1.98
7	1	1	1	NB	CT	I	L	2012	159	0.317	16.6	18.0	2.89
12	3	1	1	NB	CT	I	L	2012	159	0.238	16.4	15.5	1.66
28	2	1	2	B	CT	NI	L	2012	159	0.268	15.6	12.9	0.95
30	3	1	2	B	CT	NI	L	2012	159	0.199	17.1	13.8	0.678
31	1	1	2	B	CT	NI	L	2012	159	0.269	16.1	14.8	1.9
43	1	2	2	NB	CT	NI	L	2012	159	0.223	17.5	13.1	1.68
46	2	2	2	NB	CT	NI	L	2012	159	0.265	17.6	13.2	1.62
48	3	2	2	NB	CT	NI	L	2012	159	0.159	16.4	10.6	0.822
14	1	2	1	B	NT	I	L	2012	159	0.276	17.3	15.3	1.07
21	2	2	1	B	NT	I	L	2012	159	0.307	16.9	15.4	0.849
23	3	2	1	B	NT	I	L	2012	159	0.253	16.0	14.7	1.82
2	1	1	1	NB	NT	I	L	2012	159	0.282	17.6	18.1	1.05

5	3	1	1	NB	NT	I	L	2012	159	0.28	16.8	15.8	1.54
9	2	1	1	NB	NT	I	L	2012	159	0.255	17.4	17.2	2.09
32	1	1	2	B	NT	NI	L	2012	159	0.247	17.1	13.8	1.59
33	2	1	2	B	NT	NI	L	2012	159	0.269	16.8	13.9	0.893
35	3	1	2	B	NT	NI	L	2012	159	0.233	17.5	14.2	1.49
38	1	2	2	NB	NT	NI	L	2012	159	0.312	17.4	14.2	0.298
41	3	2	2	NB	NT	NI	L	2012	159	0.284	17.1	14.4	1.23
45	2	2	2	NB	NT	NI	L	2012	159	0.275	18.6	14.4	1.17
19	1	2	1	B	CT	I	H	2012	173	0.303	29.6	32.2	6.42
22	2	2	1	B	CT	I	H	2012	173	0.424	28.4	31.7	4.07
24	3	2	1	B	CT	I	H	2012	173	0.414	27.4	29.7	4.05
1	1	1	1	NB	CT	I	H	2012	173	0.421	28.3	30.0	4.93
6	3	1	1	NB	CT	I	H	2012	173	0.357	28.9	33.1	6.35
10	2	1	1	NB	CT	I	H	2012	173	0.367	30.1	33.1	5.07
25	1	1	2	B	CT	NI	H	2012	173	0.054	29.0	31.5	0.712
34	2	1	2	B	CT	NI	H	2012	173	0.062	28.6	34.9	0.478
36	3	1	2	B	CT	NI	H	2012	173	0.07	31.2	35.1	0.664
37	1	2	2	NB	CT	NI	H	2012	173	0.083	28.3	29.8	0.774
40	2	2	2	NB	CT	NI	H	2012	173	0.078	27.6	27.8	0.647
42	3	2	2	NB	CT	NI	H	2012	173	0.09	27.6	28.9	1.16
15	2	2	1	B	NT	I	H	2012	173	0.136	32.2	35.6	1.83
17	3	2	1	B	NT	I	H	2012	173	0.382	28.4	30.5	6.06
20	1	2	1	B	NT	I	H	2012	173	0.288	29.8	32.3	7.69
3	2	1	1	NB	NT	I	H	2012	173	0.334	27.6	29.3	5.95
8	1	1	1	NB	NT	I	H	2012	173	0.338	27.3	29.2	8.1
11	3	1	1	NB	NT	I	H	2012	173	0.366	29.3	32.1	4.8
26	1	1	2	B	NT	NI	H	2012	173	0.094	28.2	31.8	0.488
27	2	1	2	B	NT	NI	H	2012	173	0.076	30.5	33.3	0.595
29	3	1	2	B	NT	NI	H	2012	173	0.069	31.1	36.1	0.504
39	2	2	2	NB	NT	NI	H	2012	173	0.07	27.2	27.4	0.802
44	1	2	2	NB	NT	NI	H	2012	173	0.088	26.8	26.9	1.22
47	3	2	2	NB	NT	NI	H	2012	173	0.14	27.0	26.5	0.833
13	1	2	1	B	CT	I	L	2012	173	0.352	29.3	32.1	5.18
16	2	2	1	B	CT	I	L	2012	173	0.407	28.4	30.8	6.63
18	3	2	1	B	CT	I	L	2012	173	0.406	27.7	31.3	3.04
4	2	1	1	NB	CT	I	L	2012	173	0.387	28.0	31.3	5.99
7	1	1	1	NB	CT	I	L	2012	173	0.379	28.3	31.5	3.65
12	3	1	1	NB	CT	I	L	2012	173	0.113	31.0	33.4	3.87
28	2	1	2	B	CT	NI	L	2012	173	0.066	29.3	33.7	0.763
30	3	1	2	B	CT	NI	L	2012	173	0.082	30.4	35.8	0.557
31	1	1	2	B	CT	NI	L	2012	173	0.032	28.3	31.4	1.05
43	1	2	2	NB	CT	NI	L	2012	173	0.081	27.8	28.3	0.782
46	2	2	2	NB	CT	NI	L	2012	173	0.097	27.8	28.2	0.749

48	3	2	2	NB	CT	NI	L	2012	173	0.085	26.8	27.4	0.898
14	1	2	1	B	NT	I	L	2012	173	0.117	32.8	35.5	1.97
21	2	2	1	B	NT	I	L	2012	173	0.306	30.5	31.7	8.72
23	3	2	1	B	NT	I	L	2012	173	0.131	30.8	31.6	1.5
2	1	1	1	NB	NT	I	L	2012	173	0.396	27.4	30.1	5.54
5	3	1	1	NB	NT	I	L	2012	173	0.386	28.2	30.6	2.82
9	2	1	1	NB	NT	I	L	2012	173	0.301	28.0	32.1	3.07
32	1	1	2	B	NT	NI	L	2012	173	0.11	29.1	32.8	0.618
33	2	1	2	B	NT	NI	L	2012	173	0.082	29.3	31.8	0.424
35	3	1	2	B	NT	NI	L	2012	173	0.083	29.0	36.5	0.817
38	1	2	2	NB	NT	NI	L	2012	173	0.068	27.8	28.2	0.726
41	3	2	2	NB	NT	NI	L	2012	173	0.172	27.2	27.3	0.9
45	2	2	2	NB	NT	NI	L	2012	173	0.131	26.1	28.0	1.04
19	1	2	1	B	CT	I	H	2012	186	0.181	28.9	29.4	1.98
22	2	2	1	B	CT	I	H	2012	186	0.115	28.3	27.9	3.43
24	3	2	1	B	CT	I	H	2012	186	0.133	28.1	27.7	3.93
1	1	1	1	NB	CT	I	H	2012	186	0.252	26.9	25.6	3.6
6	3	1	1	NB	CT	I	H	2012	186	0.223	27.9	27.4	3.21
10	2	1	1	NB	CT	I	H	2012	186	0.225	27.4	26.3	4.1
25	1	1	2	B	CT	NI	H	2012	186	0.065	32.2	32.4	0.627
34	2	1	2	B	CT	NI	H	2012	186	0.011	32.7	36.0	0.585
36	3	1	2	B	CT	NI	H	2012	186	0.044	36.1	37.8	0.522
37	1	2	2	NB	CT	NI	H	2012	186	0.031	34.2	36.9	0.598
40	2	2	2	NB	CT	NI	H	2012	186	0.036	33.9	43.1	0.828
42	3	2	2	NB	CT	NI	H	2012	186	0.051	33.9	44.0	0.727
15	2	2	1	B	NT	I	H	2012	186	0.015	31.9	31.8	0.616
17	3	2	1	B	NT	I	H	2012	186	0.164	29.7	28.2	2.43
20	1	2	1	B	NT	I	H	2012	186	0.119	30.1	30.6	1.65
3	2	1	1	NB	NT	I	H	2012	186	0.285	27.0	26.3	4.81
8	1	1	1	NB	NT	I	H	2012	186	0.241	26.5	26.1	5.03
11	3	1	1	NB	NT	I	H	2012	186	0.101	26.8	26.9	2.62
26	1	1	2	B	NT	NI	H	2012	186	0.034	33.0	34.9	0.374
27	2	1	2	B	NT	NI	H	2012	186	0.036	33.6	35.3	0.499
29	3	1	2	B	NT	NI	H	2012	186	0.022	36.0	36.3	0.41
39	2	2	2	NB	NT	NI	H	2012	186	0.026	32.9	43.4	0.612
44	1	2	2	NB	NT	NI	H	2012	186	0.031	32.2	35.9	0.727
47	3	2	2	NB	NT	NI	H	2012	186	0.051	33.4	40.8	0.964
13	1	2	1	B	CT	I	L	2012	186	0.158	28.1	29.1	2.41
16	2	2	1	B	CT	I	L	2012	186	0.194	28.7	27.8	2.66
18	3	2	1	B	CT	I	L	2012	186	0.192	28.2	27.4	3.2
4	2	1	1	NB	CT	I	L	2012	186	0.206	26.9	26.2	5.5
7	1	1	1	NB	CT	I	L	2012	186	0.211	27.1	26.1	3.39
12	3	1	1	NB	CT	I	L	2012	186	0.042	29.1	28.6	2.38

28	2	1	2	B	CT	NI	L	2012	186	0.045	32.5	37.0	0.637
30	3	1	2	B	CT	NI	L	2012	186	0.036	44.2	40.8	0.388
31	1	1	2	B	CT	NI	L	2012	186	0.032	32.3	34.3	0.702
43	1	2	2	NB	CT	NI	L	2012	186	0.029	33.4	42.4	0.629
46	2	2	2	NB	CT	NI	L	2012	186	0.037	32.8	42.5	0.629
48	3	2	2	NB	CT	NI	L	2012	186	0.043	34.8	44.9	0.583
14	1	2	1	B	NT	I	L	2012	186	0.06	31.2	31.7	1.04
21	2	2	1	B	NT	I	L	2012	186	0.168	29.8	29.7	1.88
23	3	2	1	B	NT	I	L	2012	186	0.16	30.4	29.6	1.31
2	1	1	1	NB	NT	I	L	2012	186	0.279	26.8	26.2	4
5	3	1	1	NB	NT	I	L	2012	186	0.25	26.9	26.1	2.93
9	2	1	1	NB	NT	I	L	2012	186	0.144	27.2	26.7	3.69
32	1	1	2	B	NT	NI	L	2012	186	0.042	32.8	35.5	0.638
33	2	1	2	B	NT	NI	L	2012	186	0.044	32.7	36.1	0.166
35	3	1	2	B	NT	NI	L	2012	186	0.043	36.3	38.5	0.579
38	1	2	2	NB	NT	NI	L	2012	186	0.058	33.0	40.2	0.694
41	3	2	2	NB	NT	NI	L	2012	186	0.059	32.9	40.3	0.749
45	2	2	2	NB	NT	NI	L	2012	186	0.054	34.3	39.3	0.78
19	1	2	1	B	CT	I	H	2012	200	0.254	27.9	29.8	5.25
22	2	2	1	B	CT	I	H	2012	200	0.197	27.2	27.3	4.15
24	3	2	1	B	CT	I	H	2012	200	0.292	27.2	26.9	5.53
1	1	1	1	NB	CT	I	H	2012	200	0.292	28.4	28.2	5.98
6	3	1	1	NB	CT	I	H	2012	200	0.213	26.8	27.5	6.32
10	2	1	1	NB	CT	I	H	2012	200	0.27	26.3	27.7	5.86
25	1	1	2	B	CT	NI	H	2012	200	0.161	29.2	28.8	2.69
34	2	1	2	B	CT	NI	H	2012	200	0.158	27.8	28.4	3.31
36	3	1	2	B	CT	NI	H	2012	200	0.174	28.9	27.8	3.54
37	1	2	2	NB	CT	NI	H	2012	200	0.186	29.1	28.3	4.65
40	2	2	2	NB	CT	NI	H	2012	200	0.173	29.1	27.4	3.84
42	3	2	2	NB	CT	NI	H	2012	200	0.227	27.3	27.5	3.59
15	2	2	1	B	NT	I	H	2012	200	0.207	29.9	30.6	2.84
17	3	2	1	B	NT	I	H	2012	200	0.255	27.0	27.3	4.06
20	1	2	1	B	NT	I	H	2012	200	0.3	28.5	28.1	2.9
3	2	1	1	NB	NT	I	H	2012	200	0.24	27.7	28.8	4.98
8	1	1	1	NB	NT	I	H	2012	200	0.261	26.6	27.4	5.67
11	3	1	1	NB	NT	I	H	2012	200	0.217	26.8	27.7	6.03
26	1	1	2	B	NT	NI	H	2012	200	0.203	29.5	29.4	1.65
27	2	1	2	B	NT	NI	H	2012	200	0.181	28.2	29.5	1.86
29	3	1	2	B	NT	NI	H	2012	200	0.199	28.7	28.6	2.51
39	2	2	2	NB	NT	NI	H	2012	200	0.257	28.7	27.9	5.55
44	1	2	2	NB	NT	NI	H	2012	200	0.186	29.1	28.8	6.15
47	3	2	2	NB	NT	NI	H	2012	200	0.241	29.1	27.6	4.69
13	1	2	1	B	CT	I	L	2012	200	0.3	29.2	30.1	3.49

16	2	2	1	B	CT	I	L	2012	200	0.264	22.4	27.2	9.64
18	3	2	1	B	CT	I	L	2012	200	0.279	28.0	27.0	8.1
4	2	1	1	NB	CT	I	L	2012	200	0.269	27.2	28.2	7.84
7	1	1	1	NB	CT	I	L	2012	200	0.239	27.4	21.9	4.62
12	3	1	1	NB	CT	I	L	2012	200	0.3	27.3	28.4	6.71
28	2	1	2	B	CT	NI	L	2012	200	0.153	28.0	28.6	3.7
30	3	1	2	B	CT	NI	L	2012	200	0.234	28.2	27.5	4.45
31	1	1	2	B	CT	NI	L	2012	200	0.24	29.5	29.3	5.47
43	1	2	2	NB	CT	NI	L	2012	200	0.223	29.2	29.1	4.99
46	2	2	2	NB	CT	NI	L	2012	200	0.157	29.2	27.4	7.11
48	3	2	2	NB	CT	NI	L	2012	200	0.245	29.4	27.3	4.19
14	1	2	1	B	NT	I	L	2012	200	0.288	28.0	30.6	5.48
21	2	2	1	B	NT	I	L	2012	200	0.262	26.9	27.2	8.5
23	3	2	1	B	NT	I	L	2012	200	0.2	27.4	27.3	3.45
2	1	1	1	NB	NT	I	L	2012	200	0.22	27.1	27.6	7.56
5	3	1	1	NB	NT	I	L	2012	200	0.295	26.9	27.8	6.89
9	2	1	1	NB	NT	I	L	2012	200	0.272	27.1	27.2	6.01
32	1	1	2	B	NT	NI	L	2012	200	0.207	29.7	28.7	5.05
33	2	1	2	B	NT	NI	L	2012	200	0.17	29.1	28.6	3.66
35	3	1	2	B	NT	NI	L	2012	200	0.225	28.4	28.8	3.91
38	1	2	2	NB	NT	NI	L	2012	200	0.246	28.5	27.4	4.57
41	3	2	2	NB	NT	NI	L	2012	200	0.239	29.4	27.1	5.2
45	2	2	2	NB	NT	NI	L	2012	200	0.245	28.7	27.9	10.2
19	1	2	1	B	CT	I	H	2012	213	0.2	27.3	26.4	6.45
22	2	2	1	B	CT	I	H	2012	213	0.241	26.6	25.8	8.49
24	3	2	1	B	CT	I	H	2012	213	0.242	26.7	25.9	7.1
1	1	1	1	NB	CT	I	H	2012	213	0.266	26.8	26.2	6.22
6	3	1	1	NB	CT	I	H	2012	213	0.195	26.9	26.7	7.8
10	2	1	1	NB	CT	I	H	2012	213	0.22	26.4	26.2	5
25	1	1	2	B	CT	NI	H	2012	213	0.057	31.9	30.1	1.22
34	2	1	2	B	CT	NI	H	2012	213	0.118	32.0	30.5	1.59
36	3	1	2	B	CT	NI	H	2012	213	0.077	32.1	30.6	1.13
37	1	2	2	NB	CT	NI	H	2012	213	0.14	31.8	30.3	1.63
40	2	2	2	NB	CT	NI	H	2012	213	0.093	32.1	30.4	1.63
42	3	2	2	NB	CT	NI	H	2012	213	0.106	32.6	30.9	1.33
15	2	2	1	B	NT	I	H	2012	213	0.103	32.1	30.0	0.898
17	3	2	1	B	NT	I	H	2012	213	0.224	27.1	26.2	4.08
20	1	2	1	B	NT	I	H	2012	213	0.148	28.3	27.2	3.74
3	2	1	1	NB	NT	I	H	2012	213	0.249	26.7	26.3	6
8	1	1	1	NB	NT	I	H	2012	213	0.173	26.6	26.2	5.4
11	3	1	1	NB	NT	I	H	2012	213	0.082	27.3	27.2	4.2
26	1	1	2	B	NT	NI	H	2012	213	0.053	32.7	30.8	0.751
27	2	1	2	B	NT	NI	H	2012	213	0.045	32.7	31.2	0.668

29	3	1	2	B	NT	NI	H	2012	213	0.078	32.8	31.3	1.02
39	2	2	2	NB	NT	NI	H	2012	213	0.088	31.8	30.6	0.928
44	1	2	2	NB	NT	NI	H	2012	213	0.082	31.6	30.1	1.22
47	3	2	2	NB	NT	NI	H	2012	213	0.113	31.6	30.4	1.56
13	1	2	1	B	CT	I	L	2012	213	0.212	27.4	26.6	7.71
16	2	2	1	B	CT	I	L	2012	213	0.105	26.8	26.0	8.4
18	3	2	1	B	CT	I	L	2012	213	0.288	26.8	26.2	10.3
4	2	1	1	NB	CT	I	L	2012	213	0.223	26.5	26.2	6.33
7	1	1	1	NB	CT	I	L	2012	213	0.215	26.6	26.1	5.02
12	3	1	1	NB	CT	I	L	2012	213	0.181	27.6	27.5	6.09
28	2	1	2	B	CT	NI	L	2012	213	0.014	32.3	30.8	1.17
30	3	1	2	B	CT	NI	L	2012	213	0.105	31.9	30.2	2.67
31	1	1	2	B	CT	NI	L	2012	213	0.125	32.2	30.0	2.05
43	1	2	2	NB	CT	NI	L	2012	213	0.067	32.4	30.4	1.12
46	2	2	2	NB	CT	NI	L	2012	213	0.122	32.1	30.2	1.82
48	3	2	2	NB	CT	NI	L	2012	213	0.094	32.5	30.1	1.85
14	1	2	1	B	NT	I	L	2012	213	0.076	32.2	30.9	1.06
21	2	2	1	B	NT	I	L	2012	213	0.161	27.6	26.5	5.24
23	3	2	1	B	NT	I	L	2012	213	0.099	29.9	28.3	2.85
2	1	1	1	NB	NT	I	L	2012	213	0.144	26.8	26.4	9.45
5	3	1	1	NB	NT	I	L	2012	213	0.209	26.9	26.6	6.31
9	2	1	1	NB	NT	I	L	2012	213	0.175	26.6	26.4	5.78
32	1	1	2	B	NT	NI	L	2012	213	0.076	32.8	31.2	1.7
33	2	1	2	B	NT	NI	L	2012	213	0.09	32.8	31.4	1.11
35	3	1	2	B	NT	NI	L	2012	213	0.074	32.7	31.1	1.42
38	1	2	2	NB	NT	NI	L	2012	213	0.096	31.8	30.4	1.22
41	3	2	2	NB	NT	NI	L	2012	213	0.056	32.7	30.5	1.92
45	2	2	2	NB	NT	NI	L	2012	213	0.1	31.5	29.8	1.52
19	1	2	1	B	CT	I	H	2012	228	0.151	24.2	23.9	8.58
22	2	2	1	B	CT	I	H	2012	228	0.128	24.0	23.7	5.5
24	3	2	1	B	CT	I	H	2012	228	0.13	23.9	23.6	5.03
1	1	1	1	NB	CT	I	H	2012	228	0.169	23.1	22.7	6.83
6	3	1	1	NB	CT	I	H	2012	228	0.145	23.7	23.4	5.4
10	2	1	1	NB	CT	I	H	2012	228	0.092	23.1	23.0	2.7
25	1	1	2	B	CT	NI	H	2012	228	0.026	27.2	25.7	0.798
34	2	1	2	B	CT	NI	H	2012	228	0.04	27.3	25.9	0.7395
36	3	1	2	B	CT	NI	H	2012	228	0.045	27.3	26.1	0.681
37	1	2	2	NB	CT	NI	H	2012	228	0.069	27.2	25.9	1.07
40	2	2	2	NB	CT	NI	H	2012	228	0.042	27.5	23.7	0.962
42	3	2	2	NB	CT	NI	H	2012	228	0.045	26.3	23.8	0.894
15	2	2	1	B	NT	I	H	2012	228	0.089	27.7	27.6	0.719
17	3	2	1	B	NT	I	H	2012	228	0.101	24.1	23.4	4.08
20	1	2	1	B	NT	I	H	2012	228	0.104	25.2	25.2	4.14

3	2	1	1	NB	NT	I	H	2012	228	0.11	22.8	22.4	6.96
8	1	1	1	NB	NT	I	H	2012	228	0.066	23.7	24.1	4.92
11	3	1	1	NB	NT	I	H	2012	228	0.125	24.7	24.5	2.77
26	1	1	2	B	NT	NI	H	2012	228	0.016	26.8	26.3	0.407
27	2	1	2	B	NT	NI	H	2012	228	0.04	25.7	26.8	0.4815
29	3	1	2	B	NT	NI	H	2012	228	0.069	24.5	27.2	0.556
39	2	2	2	NB	NT	NI	H	2012	228	0.046	27.9	26.6	0.58
44	1	2	2	NB	NT	NI	H	2012	228	0.03	27.6	26.0	0.714
47	3	2	2	NB	NT	NI	H	2012	228	0.05	27.4	25.9	0.712
13	1	2	1	B	CT	I	L	2012	228	0.144	24.2	23.7	7
16	2	2	1	B	CT	I	L	2012	228	0.106	23.5	23.1	6.73
18	3	2	1	B	CT	I	L	2012	228	0.169	23.2	23.4	5.44
4	2	1	1	NB	CT	I	L	2012	228	0.305	23.7	23.1	4.31
7	1	1	1	NB	CT	I	L	2012	228	0.202	23.6	23.4	4.41
12	3	1	1	NB	CT	I	L	2012	228	0.067	24.2	24.2	4.5
28	2	1	2	B	CT	NI	L	2012	228	0.06	26.9	25.7	1.975
30	3	1	2	B	CT	NI	L	2012	228	0.062	26.6	25.9	2.45
31	1	1	2	B	CT	NI	L	2012	228	0.058	27.1	25.5	1.5
43	1	2	2	NB	CT	NI	L	2012	228	0.029	27.1	26.4	0.874
46	2	2	2	NB	CT	NI	L	2012	228	0.067	27.0	24.3	0.994
48	3	2	2	NB	CT	NI	L	2012	228	0.08	25.1	23.2	1.12
14	1	2	1	B	NT	I	L	2012	228	0.053	27.3	27.6	1.1
21	2	2	1	B	NT	I	L	2012	228	0.17	25.4	24.9	5.13
23	3	2	1	B	NT	I	L	2012	228	0.086	26.3	25.5	2.03
2	1	1	1	NB	NT	I	L	2012	228	0.106	23.1	22.8	9.1
5	3	1	1	NB	NT	I	L	2012	228	0.214	23.8	23.2	6.28
9	2	1	1	NB	NT	I	L	2012	228	0.115	24.0	23.7	4.75
32	1	1	2	B	NT	NI	L	2012	228	0.032	28.1	27.3	1.14
33	2	1	2	B	NT	NI	L	2012	228	0.06	27.8	27.0	0.9585
35	3	1	2	B	NT	NI	L	2012	228	0.084	27.4	26.7	0.777
38	1	2	2	NB	NT	NI	L	2012	228	0.048	28.1	25.8	1.07
41	3	2	2	NB	NT	NI	L	2012	228	0.035	26.5	26.4	1.21
45	2	2	2	NB	NT	NI	L	2012	228	0.067	26.2	25.7	0.712
19	1	2	1	B	CT	I	H	2012	247	0.296	26.8	28.8	9.93
22	2	2	1	B	CT	I	H	2012	247	0.262	26.2	28.7	6.75
24	3	2	1	B	CT	I	H	2012	247	0.303	26.2	27.6	9.29
1	1	1	1	NB	CT	I	H	2012	247	0.18	26.0	26.3	5.08
6	3	1	1	NB	CT	I	H	2012	247	0.254	26.2	27.4	5.31
10	2	1	1	NB	CT	I	H	2012	247	0.189	26.0	26.2	7.98
25	1	1	2	B	CT	NI	H	2012	247	0.2765	26.6	26.5	3.195
34	2	1	2	B	CT	NI	H	2012	247	0.275	26.0	26.6	3.84
36	3	1	2	B	CT	NI	H	2012	247	0.278	27.2	26.4	2.55
37	1	2	2	NB	CT	NI	H	2012	247	0.271	29.8	27.7	6.23

40	2	2	2	NB	CT	NI	H	2012	247	0.242	27.5	28.8	6.4
42	3	2	2	NB	CT	NI	H	2012	247	0.256	27.2	29.1	5.87
15	2	2	1	B	NT	I	H	2012	247	0.228	27.3	30.2	4.19
17	3	2	1	B	NT	I	H	2012	247	0.276	26.0	27.6	4.38
20	1	2	1	B	NT	I	H	2012	247	0.274	25.9	26.9	7.06
3	2	1	1	NB	NT	I	H	2012	247	0.201	25.5	26.8	4.75
8	1	1	1	NB	NT	I	H	2012	247	0.222	25.6	26.2	5.96
11	3	1	1	NB	NT	I	H	2012	247	0.185	26.7	27.3	2.89
26	1	1	2	B	NT	NI	H	2012	247	0.295	26.3	28.0	5.33
27	2	1	2	B	NT	NI	H	2012	247	0.281	26.9	27.4	2.26
29	3	1	2	B	NT	NI	H	2012	247	0.306	26.9	26.7	3.34
39	2	2	2	NB	NT	NI	H	2012	247	0.251	29.5	28.2	4.78
44	1	2	2	NB	NT	NI	H	2012	247	0.293	27.6	27.1	4.53
47	3	2	2	NB	NT	NI	H	2012	247	0.333	27.9	27.6	6.42
13	1	2	1	B	CT	I	L	2012	247	0.289	25.4	26.9	7.67
16	2	2	1	B	CT	I	L	2012	247	0.248	25.8	26.6	7.4
18	3	2	1	B	CT	I	L	2012	247	0.265	25.9	26.7	6.53
4	2	1	1	NB	CT	I	L	2012	247	0.218	26.1	26.5	6.05
7	1	1	1	NB	CT	I	L	2012	247	0.215	26.1	26.1	3.36
12	3	1	1	NB	CT	I	L	2012	247	0.282	26.9	29.0	5.32
28	2	1	2	B	CT	NI	L	2012	247	0.19	26.9	27.0	2.79
30	3	1	2	B	CT	NI	L	2012	247	0.326	27.0	25.6	5.29
31	1	1	2	B	CT	NI	L	2012	247	0.377	26.7	27.0	3.39
43	1	2	2	NB	CT	NI	L	2012	247	0.264	27.7	27.5	13.1
46	2	2	2	NB	CT	NI	L	2012	247	0.316	27.4	27.7	8
48	3	2	2	NB	CT	NI	L	2012	247	0.266	26.9	26.9	4.13
14	1	2	1	B	NT	I	L	2012	247	0.315	26.4	27.3	4.19
21	2	2	1	B	NT	I	L	2012	247	0.226	26.4	27.3	5.96
23	3	2	1	B	NT	I	L	2012	247	0.283	26.3	27.8	3.14
2	1	1	1	NB	NT	I	L	2012	247	0.246	25.4	26.2	5.06
5	3	1	1	NB	NT	I	L	2012	247	0.262	26.5	27.1	3.4
9	2	1	1	NB	NT	I	L	2012	247	0.232	26.0	26.3	7.02
32	1	1	2	B	NT	NI	L	2012	247	0.326	28.7	26.9	6.62
33	2	1	2	B	NT	NI	L	2012	247	0.258	26.6	27.6	2.19
35	3	1	2	B	NT	NI	L	2012	247	0.279	27.3	26.9	5.42
38	1	2	2	NB	NT	NI	L	2012	247	0.3	27.5	27.4	5.7
41	3	2	2	NB	NT	NI	L	2012	247	0.29	28.2	27.4	4.53
45	2	2	2	NB	NT	NI	L	2012	247	0.296	29.5	27.5	4.14
19	1	2	1	B	CT	I	H	2012	258	0.165	23.5	23.7	6.97
22	2	2	1	B	CT	I	H	2012	258	0.152	22.6	23.3	4.34
24	3	2	1	B	CT	I	H	2012	258	0.167	23.5	25.9	4.47
1	1	1	1	NB	CT	I	H	2012	258	0.166	22.7	22.3	2.04
6	3	1	1	NB	CT	I	H	2012	258	0.097	22.9	22.3	2.95

10	2	1	1	NB	CT	I	H	2012	258	0.095	22.8	22.4	3.92
25	1	1	2	B	CT	NI	H	2012	258	0.238	23.9	21.8	2.64
34	2	1	2	B	CT	NI	H	2012	258	0.193	24.3	22.2	1.76
36	3	1	2	B	CT	NI	H	2012	258	0.207	24.4	22.8	1.06
37	1	2	2	NB	CT	NI	H	2012	258	0.119	24.7	22.8	2.51
40	2	2	2	NB	CT	NI	H	2012	258	0.186	24.9	22.8	2.14
42	3	2	2	NB	CT	NI	H	2012	258	0.148	25.1	22.9	2.84
15	2	2	1	B	NT	I	H	2012	258	0.223	24.3	24.9	1.19
17	3	2	1	B	NT	I	H	2012	258	0.169	23.7	25.4	2.49
20	1	2	1	B	NT	I	H	2012	258	0.111	24.0	23.8	4.41
3	2	1	1	NB	NT	I	H	2012	258	0.164	22.7	22.4	3
8	1	1	1	NB	NT	I	H	2012	258	0.106	23.3	22.8	3.14
11	3	1	1	NB	NT	I	H	2012	258	0.125	23.4	22.7	1.74
26	1	1	2	B	NT	NI	H	2012	258	0.165	24.6	22.7	2.14
27	2	1	2	B	NT	NI	H	2012	258	0.175	24.4	22.7	1.05
29	3	1	2	B	NT	NI	H	2012	258	0.198	24.4	22.8	1.44
39	2	2	2	NB	NT	NI	H	2012	258	0.173	24.6	22.6	2.05
44	1	2	2	NB	NT	NI	H	2012	258	0.159	24.4	23.2	2.5
47	3	2	2	NB	NT	NI	H	2012	258	0.148	25.0	23.7	2.82
13	1	2	1	B	CT	I	L	2012	258	0.121	24.0	22.6	4.94
16	2	2	1	B	CT	I	L	2012	258	0.115	23.0	23.5	3.91
18	3	2	1	B	CT	I	L	2012	258	0.098	23.1	24.1	4.49
4	2	1	1	NB	CT	I	L	2012	258	0.113	22.8	22.2	3.56
7	1	1	1	NB	CT	I	L	2012	258	0.145	22.7	22.4	2.89
12	3	1	1	NB	CT	I	L	2012	258	0.178	23.3	22.4	1.7
28	2	1	2	B	CT	NI	L	2012	258	0.148	24.6	22.6	1.47
30	3	1	2	B	CT	NI	L	2012	258	0.128	24.1	22.7	2.01
31	1	1	2	B	CT	NI	L	2012	258	0.203	24.4	22.1	1.65
43	1	2	2	NB	CT	NI	L	2012	258	0.1	24.6	23.1	3.13
46	2	2	2	NB	CT	NI	L	2012	258	0.166	24.9	22.8	2.96
48	3	2	2	NB	CT	NI	L	2012	258	0.183	24.2	22.1	2.19
14	1	2	1	B	NT	I	L	2012	258	0.182	24.2	24.9	1.96
21	2	2	1	B	NT	I	L	2012	258	0.126	23.6	24.3	3.44
23	3	2	1	B	NT	I	L	2012	258	0.078	24.2	25.4	1.91
2	1	1	1	NB	NT	I	L	2012	258	0.098	22.6	22.4	2.29
5	3	1	1	NB	NT	I	L	2012	258	0.156	23.1	22.6	1.57
9	2	1	1	NB	NT	I	L	2012	258	0.167	22.9	22.6	3.86
32	1	1	2	B	NT	NI	L	2012	258	0.175	23.3	22.9	2.3
33	2	1	2	B	NT	NI	L	2012	258	0.155	24.4	22.6	0.818
35	3	1	2	B	NT	NI	L	2012	258	0.179	24.6	23.2	1.99
38	1	2	2	NB	NT	NI	L	2012	258	0.197	24.4	22.8	2.28
41	3	2	2	NB	NT	NI	L	2012	258	0.146	24.9	23.3	2.1
45	2	2	2	NB	NT	NI	L	2012	258	0.228	24.7	23.2	1.98

19	1	2	1	B	CT	I	H	2012	273	0.167	21.7	20.9	4.19
22	2	2	1	B	CT	I	H	2012	273	0.199	21.7	21.1	2.43
24	3	2	1	B	CT	I	H	2012	273	0.192	21.9	20.8	2.36
1	1	1	1	NB	CT	I	H	2012	273	0.204	22.0	21.8	2.31
6	3	1	1	NB	CT	I	H	2012	273	0.162	22.3	22.8	2.15
10	2	1	1	NB	CT	I	H	2012	273	0.117	22.0	22.0	2.41
25	1	1	2	B	CT	NI	H	2012	273	0.19	22.6	21.2	1.58
34	2	1	2	B	CT	NI	H	2012	273	0.194	22.8	21.8	1.17
36	3	1	2	B	CT	NI	H	2012	273	0.158	23.5	22.5	1.02
37	1	2	2	NB	CT	NI	H	2012	273	0.163	23.3	21.8	1.87
40	2	2	2	NB	CT	NI	H	2012	273	0.125	23.4	21.4	1.35
42	3	2	2	NB	CT	NI	H	2012	273	0.119	23.9	21.9	1.98
15	2	2	1	B	NT	I	H	2012	273	0.174	22.9	22.5	0.749
17	3	2	1	B	NT	I	H	2012	273	0.147	22.4	21.8	1.39
20	1	2	1	B	NT	I	H	2012	273	0.123	22.6	21.8	2.5
3	2	1	1	NB	NT	I	H	2012	273	0.145	21.8	21.6	2.25
8	1	1	1	NB	NT	I	H	2012	273	0.161	22.1	21.9	1.98
11	3	1	1	NB	NT	I	H	2012	273	0.084	22.3	22.5	1.33
26	1	1	2	B	NT	NI	H	2012	273	0.189	23.6	21.8	1.47
27	2	1	2	B	NT	NI	H	2012	273	0.174	23.5	21.9	0.669
29	3	1	2	B	NT	NI	H	2012	273	0.17	23.6	22.2	1.04
39	2	2	2	NB	NT	NI	H	2012	273	0.143	23.1	21.5	1.75
44	1	2	2	NB	NT	NI	H	2012	273	0.13	22.8	21.5	1.5
47	3	2	2	NB	NT	NI	H	2012	273	0.115	23.1	22.2	1.9
13	1	2	1	B	CT	I	L	2012	273	0.185	21.5	20.9	2.39
16	2	2	1	B	CT	I	L	2012	273	0.162	21.8	21.2	2.31
18	3	2	1	B	CT	I	L	2012	273	0.163	21.9	20.9	2.4
4	2	1	1	NB	CT	I	L	2012	273	0.101	22.1	22.1	2.27
7	1	1	1	NB	CT	I	L	2012	273	0.188	21.9	21.7	2.06
12	3	1	1	NB	CT	I	L	2012	273	0.14	22.2	22.3	1.55
28	2	1	2	B	CT	NI	L	2012	273	0.119	23.6	22.4	1.11
30	3	1	2	B	CT	NI	L	2012	273	0.098	22.8	21.9	1.36
31	1	1	2	B	CT	NI	L	2012	273	0.127	23.1	21.8	1.12
43	1	2	2	NB	CT	NI	L	2012	273	0.15	23.1	21.6	2.17
46	2	2	2	NB	CT	NI	L	2012	273	0.132	23.6	22.0	1.65
48	3	2	2	NB	CT	NI	L	2012	273	0.189	22.9	21.2	1.55
14	1	2	1	B	NT	I	L	2012	273	0.18	22.9	22.7	1.37
21	2	2	1	B	NT	I	L	2012	273	0.129	22.3	21.4	1.88
23	3	2	1	B	NT	I	L	2012	273	0.12	23.0	22.3	1.39
2	1	1	1	NB	NT	I	L	2012	273	0.182	21.9	21.5	1.4
5	3	1	1	NB	NT	I	L	2012	273	0.135	22.2	22.4	1.09
9	2	1	1	NB	NT	I	L	2012	273	0.16	21.8	21.7	1.98
32	1	1	2	B	NT	NI	L	2012	273	0.153	23.6	22.0	1.6

33	2	1	2	B	NT	NI	L	2012	273	0.149	23.2	21.7	0.593
35	3	1	2	B	NT	NI	L	2012	273	0.166	23.6	22.6	1.41
38	1	2	2	NB	NT	NI	L	2012	273	0.167	23.0	21.7	1.6
41	3	2	2	NB	NT	NI	L	2012	273	0.167	23.3	22.0	1.69
45	2	2	2	NB	NT	NI	L	2012	273	0.166	23.3	21.8	1.65
19	1	2	1	B	CT	I	H	2012	287	0.265	18.9	22.0	2.14
22	2	2	1	B	CT	I	H	2012	287	0.284	19.4	21.8	2.5
24	3	2	1	B	CT	I	H	2012	287	0.307	18.6	20.7	2.38
1	1	1	1	NB	CT	I	H	2012	287	0.302	18.9	21.1	5.43
6	3	1	1	NB	CT	I	H	2012	287	0.273	19.2	22.2	2.27
10	2	1	1	NB	CT	I	H	2012	287	0.248	19.1	21.2	3.02
25	1	1	2	B	CT	NI	H	2012	287	0.285	18.0	19.9	1.33
34	2	1	2	B	CT	NI	H	2012	287	0.294	19.6	23.8	3.22
36	3	1	2	B	CT	NI	H	2012	287	0.225	19.4	22.6	1.34
37	1	2	2	NB	CT	NI	H	2012	287	0.278	18.3	21.9	3.31
40	2	2	2	NB	CT	NI	H	2012	287	0.266	19.2	19.8	2.69
42	3	2	2	NB	CT	NI	H	2012	287	0.25	18.6	20.1	2.06
15	2	2	1	B	NT	I	H	2012	287	0.271	20.4	24.8	3.01
17	3	2	1	B	NT	I	H	2012	287	0.32	18.8	20.7	3.47
20	1	2	1	B	NT	I	H	2012	287	0.272	19.5	22.0	2.33
3	2	1	1	NB	NT	I	H	2012	287	0.218	19.1	20.8	2.86
8	1	1	1	NB	NT	I	H	2012	287	0.229	18.6	20.1	1.77
11	3	1	1	NB	NT	I	H	2012	287	0.268	19.1	21.2	1.71
26	1	1	2	B	NT	NI	H	2012	287	0.246	18.8	22.6	1.38
27	2	1	2	B	NT	NI	H	2012	287	0.246	18.6	23.2	0.942
29	3	1	2	B	NT	NI	H	2012	287	0.255	19.2	21.4	1.74
39	2	2	2	NB	NT	NI	H	2012	287	0.246	18.7	20.5	2.01
44	1	2	2	NB	NT	NI	H	2012	287	0.275	18.7	19.7	4.52
47	3	2	2	NB	NT	NI	H	2012	287	0.287	18.9	18.9	2.53
13	1	2	1	B	CT	I	L	2012	287	0.306	18.9	22.1	2.76
16	2	2	1	B	CT	I	L	2012	287	0.33	19.2	20.9	2.01
18	3	2	1	B	CT	I	L	2012	287	0.361	18.4	20.4	1.81
4	2	1	1	NB	CT	I	L	2012	287	0.281	19.1	21.6	1.94
7	1	1	1	NB	CT	I	L	2012	287	0.26	18.9	20.9	2.33
12	3	1	1	NB	CT	I	L	2012	287	0.277	19.8	22.4	3.7
28	2	1	2	B	CT	NI	L	2012	287	0.281	19.9	23.2	2.21
30	3	1	2	B	CT	NI	L	2012	287	0.29	18.8	21.9	2.28
31	1	1	2	B	CT	NI	L	2012	287	0.304	18.9	22.2	2.13
43	1	2	2	NB	CT	NI	L	2012	287	0.316	18.4	20.3	4.05
46	2	2	2	NB	CT	NI	L	2012	287	0.264	18.8	20.1	1.93
48	3	2	2	NB	CT	NI	L	2012	287	0.292	18.2	20.3	2.93
14	1	2	1	B	NT	I	L	2012	287	0.246	20.3	23.9	2.1
21	2	2	1	B	NT	I	L	2012	287	0.311	18.9	20.9	2.14

23	3	2	1	B	NT	I	L	2012	287	0.333	18.9	23.1	1.81
2	1	1	1	NB	NT	I	L	2012	287	0.279	19.1	21.2	1.97
5	3	1	1	NB	NT	I	L	2012	287	0.257	19.4	23.3	2.1
9	2	1	1	NB	NT	I	L	2012	287	0.218	19.2	22.1	2.05
32	1	1	2	B	NT	NI	L	2012	287	0.261	18.2	21.6	3.01
33	2	1	2	B	NT	NI	L	2012	287	0.294	19.4	23.3	3.23
35	3	1	2	B	NT	NI	L	2012	287	0.281	19.8	22.8	2.16
38	1	2	2	NB	NT	NI	L	2012	287	0.339	19.0	21.0	2.36
41	3	2	2	NB	NT	NI	L	2012	287	0.291	18.9	20.1	2.36
45	2	2	2	NB	NT	NI	L	2012	287	0.272	18.5	21.5	3.47
19	1	2	1	B	CT	I	H	2012	303	0.272	10.7	13.2	1.14
22	2	2	1	B	CT	I	H	2012	303	0.25	11.5	14.4	1.69
24	3	2	1	B	CT	I	H	2012	303	0.26	11.1	12.2	1.06
1	1	1	1	NB	CT	I	H	2012	303	0.289	11.8	11.3	3.88
6	3	1	1	NB	CT	I	H	2012	303	0.274	10.4	9.3	1.12
10	2	1	1	NB	CT	I	H	2012	303	0.214	11.4	10.8	1.27
25	1	1	2	B	CT	NI	H	2012	303	0.246	11.4	13.6	1.23
34	2	1	2	B	CT	NI	H	2012	303	0.239	13.1	17.7	1.96
36	3	1	2	B	CT	NI	H	2012	303	0.217	11.2	16.5	0.746
37	1	2	2	NB	CT	NI	H	2012	303	0.246	12.6	13.7	2
40	2	2	2	NB	CT	NI	H	2012	303	0.213	13.6	17.3	1.65
42	3	2	2	NB	CT	NI	H	2012	303	0.273	13.8	16.7	1.21
15	2	2	1	B	NT	I	H	2012	303	0.267	11.2	12.6	1.01
17	3	2	1	B	NT	I	H	2012	303	0.266	11.5	12.6	1.7
20	1	2	1	B	NT	I	H	2012	303	0.266	10.4	10.4	0.757
3	2	1	1	NB	NT	I	H	2012	303	0.23	13.2	12.3	1.28
8	1	1	1	NB	NT	I	H	2012	303	0.237	12.5	11.9	0.935
11	3	1	1	NB	NT	I	H	2012	303	0.234	11.9	10.8	0.855
26	1	1	2	B	NT	NI	H	2012	303	0.211	11.7	16.1	0.392
27	2	1	2	B	NT	NI	H	2012	303	0.167	11.6	18.9	0.646
29	3	1	2	B	NT	NI	H	2012	303	0.219	10.9	13.9	0.632
39	2	2	2	NB	NT	NI	H	2012	303	0.226	13.7	17.2	1.04
44	1	2	2	NB	NT	NI	H	2012	303	0.238	13.0	15.8	1.78
47	3	2	2	NB	NT	NI	H	2012	303	0.238	13.6	18.1	1.86
13	1	2	1	B	CT	I	L	2012	303	0.285	10.2	10.2	1.48
16	2	2	1	B	CT	I	L	2012	303	0.241	11.6	14.9	1.56
18	3	2	1	B	CT	I	L	2012	303	0.3	10.7	12.6	1.21
4	2	1	1	NB	CT	I	L	2012	303	0.27	10.6	9.6	0.745
7	1	1	1	NB	CT	I	L	2012	303	0.263	12.3	11.7	1.14
12	3	1	1	NB	CT	I	L	2012	303	0.241	11.0	10.5	1.54
28	2	1	2	B	CT	NI	L	2012	303	0.206	13.2	17.2	1.58
30	3	1	2	B	CT	NI	L	2012	303	0.198	12.4	15.1	0.703
31	1	1	2	B	CT	NI	L	2012	303	0.227	12.7	15.6	0.933

43	1	2	2	NB	CT	NI	L	2012	303	0.297	11.5	12.0	7.74
46	2	2	2	NB	CT	NI	L	2012	303	0.237	12.7	16.0	1.24
48	3	2	2	NB	CT	NI	L	2012	303	0.258	12.7	16.6	1.7
14	1	2	1	B	NT	I	L	2012	303	0.21	9.4	11.7	0.666
21	2	2	1	B	NT	I	L	2012	303	0.264	10.3	10.9	0.739
23	3	2	1	B	NT	I	L	2012	303	0.279	10.6	12.1	0.744
2	1	1	1	NB	NT	I	L	2012	303	0.316	11.8	11.3	0.812
5	3	1	1	NB	NT	I	L	2012	303	0.294	10.9	10.7	0.663
9	2	1	1	NB	NT	I	L	2012	303	0.196	11.7	11.2	1.08
32	1	1	2	B	NT	NI	L	2012	303	0.255	11.7	12.8	1.39
33	2	1	2	B	NT	NI	L	2012	303	0.271	12.4	18.8	1.7
35	3	1	2	B	NT	NI	L	2012	303	0.244	11.8	14.8	1.39
38	1	2	2	NB	NT	NI	L	2012	303	0.298	13.5	14.3	1.81
41	3	2	2	NB	NT	NI	L	2012	303	0.248	14.3	18.9	2.05
45	2	2	2	NB	NT	NI	L	2012	303	0.233	12.8	14.4	2.19

Table 1. Analysis of variance summary of the effects of burning (B), tillage (T), residue level (R), and their interactions on soil carbon (C), nitrogen (N), phosphorus (P), potassium (K), and organic matter (SOM) concentrations (g kg^{-1}), soil C:N ratio, soil pH, soil electrical conductivity, and soil bulk density (ρ_b) in the top 10 cm after wheat harvest, but prior to soybean planting each year. Also included are the ANOVA summary of the treatment effects on wheat-residue amounts, and soybean yields after 9 (2011) and 10 (2012) years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text *(P* < 0.05). This analysis ignores the irrigation treatment in the design.

		Treatment Effect						
Year	**Soil/Plant Properties**	**Burning**	**Tillage**	**B*T**	**Residue**	**B*R**	**T*R**	**B*T*R**
		——— *P* ———						
2011								
	C Concentration	0.383	0.767	0.494	0.851	0.110	0.256	0.587
	N Concentration	0.979	0.677	0.875	0.858	0.074	0.215	0.892
	C:N Ratio	0.426	0.377	0.299	0.979	0.643	0.735	0.413
	P Concentration	0.054	0.340	0.922	0.072	0.228	0.705	0.754
	K Concentration	0.976	0.604	0.571	**0.021**	0.964	0.550	0.453
	SOM Concentration	0.445	0.933	0.658	0.973	0.207	0.618	0.355
	Soil pH	0.907	0.308	0.704	**0.026**	0.260	0.991	0.928
	Electrical Conductivity	0.424	**0.037**	0.482	0.168	0.279	0.227	**0.049**
	Soil Bulk Density	0.289	0.415	0.936	0.272	**0.025**	0.133	0.387
	Wheat Residue	0.817	**0.023**	0.496	**0.008**	0.991	0.298	**0.006**
	Soybean Yield	0.682	0.738	0.632	**0.015**	0.867	0.309	0.772
2012								
	C Concentration	0.587	0.142	0.384	0.730	0.622	0.684	0.562
	N Concentration	0.451	0.127	0.650	0.608	0.843	0.592	0.774
	C:N Ratio	0.978	0.762	0.186	0.645	0.210	0.678	0.556
	P Concentration	0.629	**0.046**	0.268	**0.002**	0.953	0.967	0.875
	K Concentration	0.792	0.081	0.568	0.087	0.816	0.545	0.718
	SOM Concentration	0.832	0.123	0.646	0.640	0.931	0.678	0.982
	Soil pH	0.734	0.152	0.059	**0.044**	0.547	0.804	0.614
	Electrical Conductivity	0.740	0.391	0.451	0.144	0.520	0.948	0.935
	Soil Bulk Density	0.155	0.156	0.479	0.874	0.863	0.726	0.608
	Wheat Residue	0.735	0.059	0.334	**0.009**	0.063	0.732	0.565
	Soybean Yield	0.367	0.083	**0.005**	0.803	0.820	0.462	0.758

Table 2. Analysis of variance summary of the effects of irrigation (I), tillage (T), residue level (R), and their interactions on soil carbon (C), nitrogen (N), phosphorus (P), potassium (K), and organic matter (SOM) concentrations (g kg^{-1}), soil C:N ratio, soil pH, soil electrical conductivity, and soil bulk density (ρ_b) in the top 10 cm after wheat harvest, but prior to soybean planting each year. Also included are the ANOVA summary of the treatment effects on wheat-residue amounts, and soybean yields after 9 (2011) and 10 (2012) years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text *(P* < 0.05). This analysis ignores the burning treatment in the design.

		Treatment Effect						
Year	**Soil/Plant Properties**	**Irrigation**	**Tillage**	**I*T**	**Residue**	**I*R**	**T*R**	**I*T*R**
					P			
2011								
	C Concentration	0.448	0.767	0.847	0.889	0.696	0.347	0.761
	N Concentration	0.142	0.677	0.655	0.878	0.684	0.373	0.944
	C:N Ratio	0.351	0.377	0.631	0.991	0.574	0.693	0.722
	P Concentration	0.440	0.340	0.473	0.100	0.342	0.631	0.771
	K Concentration	**0.009**	0.604	0.611	**0.006**	0.090	0.260	0.781
	SOM Concentration	0.530	0.933	0.941	0.981	0.700	0.577	0.727
	Soil pH	**0.021**	0.308	0.308	0.054	0.971	0.995	0.338
	Electrical Conductivity	0.286	**0.037**	0.051	0.301	0.911	0.240	0.630
	Soil Bulk Density	0.553	0.415	0.774	0.389	0.702	0.316	0.860
	Wheat Residue	0.883	**0.023**	0.588	**0.010**	0.340	0.222	0.342
	Soybean Yield	**0.033**	0.738	0.342	0.126	0.491	0.609	0.801
2012								
	C Concentration	0.321	0.142	0.899	0.683	0.096	0.239	0.078
	N Concentration	0.334	0.127	0.962	0.548	0.052	0.097	0.057
	C:N Ratio	0.166	0.762	0.712	0.736	0.620	0.663	0.595
	P Concentration	0.402	**0.046**	**0.033**	**0.003**	0.796	0.974	**0.013**
	K Concentration	0.113	0.081	0.083	0.178	0.353	0.481	0.175
	SOM Concentration	0.122	0.123	0.777	0.522	**0.037**	0.488	**0.035**
	Soil pH	0.099	0.152	0.128	**0.013**	**0.008**	0.864	0.595
	Electrical Conductivity	0.236	0.391	0.938	**0.009**	**0.004**	0.941	0.606
	Soil Bulk Density	0.574	0.156	0.492	0.893	0.584	0.608	0.104
	Wheat Residue	0.090	0.059	0.170	**0.003**	0.643	0.708	0.116
	Soybean Yield	0.101	0.083	0.060	0.739	0.970	0.329	0.572

Table 3. Analysis of variance summary of the effects of burning, tillage, residue level (residue), time (sample date) and their interactions on soil respiration (R_s), 2-cm soil temperature, and 0- to 6-cm volumetric water content (VWC) after 9 (2011) and 10 (2012) years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text *(P* < 0.05). This analysis ignores the irrigation treatment in the design.

	2011			2012		
Treatment Effect	**R_s**	**Temp**	**VWC**	**R_s**	**Temp**	**VWC**
	P					
Burning	0.405	0.354	0.896	0.347	0.185	0.351
Tillage	0.144	0.230	0.224	**0.006**	0.065	0.255
Burning*Tillage	0.077	0.051	0.364	0.171	**0.012**	0.072
Residue	0.623	0.724	0.863	0.520	0.846	0.327
Burning*Residue	0.494	0.663	0.682	0.697	0.877	0.155
Tillage* Residue	0.609	0.737	0.303	0.871	0.653	0.161
Burning*Tillage* Residue	0.684	0.225	0.089	0.906	0.969	0.574
Time	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Burning*Time	0.185	0.207	0.456	0.911	0.830	0.192
Tillage*Time	**0.011**	**0.007**	**<0.001**	**0.025**	**0.013**	0.194
Residue *Time	0.328	0.520	0.229	**0.002**	**0.026**	0.065
Burning*Tillage*Time	**0.033**	**0.010**	0.604	**0.003**	**<0.001**	0.271
Burning* Residue *Time	0.227	0.391	0.760	0.941	0.963	0.218
Tillage* Residue *Time	0.401	0.128	0.350	0.898	0.198	0.580
Burning*Tillage* Residue *Time	0.345	0.623	0.979	0.746	0.363	0.756

Table 4. Analysis of variance summary of the effects of irrigation, tillage, residue level (residue), time (sample date) and their interactions on soil respiration (R_S), 2-cm soil temperature, and 0- to 6-cm volumetric water content (VWC) after 9 (2011) and 10 (2012) years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text *(P* < 0.05). This analysis ignores the burning treatment in the design.

	2011			**2012**		
Treatment Effect	**R_S**	**2-cm Temp**	**VWC**	**R_S**	**2-cm Temp**	**VWC**
			P			
Irrigation	0.849	0.280	0.061	0.173	0.092	**0.034**
Tillage	0.144	0.230	0.314	**0.002**	0.063	0.394
Irrigation*Tillage	0.547	0.766	**0.006**	**0.047**	0.342	**0.026**
Residue	0.613	0.564	0.919	0.504	0.565	0.119
Irrigation* Residue	0.426	0.182	0.956	0.259	0.393	0.256
Tillage* Residue	0.463	0.757	0.544	0.972	0.690	0.730
Irrigation*Tillage* Residue	0.831	0.483	0.864	0.413	0.824	0.967
Time	0.995	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Irrigation*Time	**<0.001**	**0.007**	**<0.001**	**<0.001**	**0.003**	**<0.001**
Tillage*Time	**0.011**	**0.007**	**<0.001**	**0.050**	**0.015**	0.117
Residue *Time	0.469	0.338	0.103	**0.007**	0.345	**0.043**
Irrigation*Tillage*Time	0.966	0.958	0.423	0.619	0.187	0.141
Irrigation* Residue *Time	0.359	0.186	0.422	0.344	0.142	0.928
Tillage* Residue *Time	**0.023**	0.149	0.226	0.948	0.280	0.804
Irrigation*Tillage* Residue *Time	0.361	0.308	0.208	0.406	0.868	0.898

Table 5. Analysis of variance summary of the effects of burning, tillage, residue level (residue), year, and their interactions on estimated season-long CO_2 emissions, after 9 (2011) and 10 (2012) years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text (P < 0.05). This analysis ignores the irrigation treatment in the design.

Treatment Effect	**Season-long CO_2 Emissions**
	—— *P* ——
Burning	**0.032**
Tillage	**0.020**
Burning*Tillage	0.249
Residue	0.505
Burning* Residue	0.421
Tillage* Residue	0.712
Burning*Tillage* Residue	0.906
Year	**<0.001**
Burning*Year	0.828
Tillage*Year	0.366
Residue *Year	0.747
Burning*Tillage*Year	0.091
Burning* Residue *Year	0.788
Tillage* Residue *Year	0.564
Burning*Tillage* Residue *Year	0.783

Table 6. Analysis of variance summary of the effects of irrigation, tillage, residue level (residue), year, and their interactions on estimated season-long CO_2 emissions, after 9 (2011) and 10 (2012) years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text ($P < 0.05$). This analysis ignores the burning treatment in the design.

Treatment Effect	**Season-long CO_2 Emissions**
	—— *P* ——
Irrigation	0.243
Tillage	**0.020**
Irrigation*Tillage	0.383
Residue	0.512
Irrigation* Residue	0.097
Tillage* Residue	0.699
Irrigation*Tillage* Residue	0.759
Year	**<0.001**
Irrigation*Year	**0.044**
Tillage*Year	0.366
Residue *Year	0.689
Irrigation*Tillage*Year	0.277
Irrigation* Residue *Year	0.926
Tillage* Residue *Year	0.455
Irrigation*Tillage* Residue *Year	0.838

Table 7. Summary of multiple linear regression coefficients for 0- to 6-cm volumetric water content (VWC), 2-cm soil temperature (Temp), and their interaction and quadratic terms for data combined across all treatments and seperatly for each treatment combination. Treatments include burning [burn (B) and no burn (NB)], irrigation [irrigated (I) and dryland (DL)], tillage [conventional tillage (CT) and no-tillage (NT)], and residue level [high (H) and low (L)]. Coefficients that were significant in the model for each term are in bold and 95% confidence intervals are in parentheses. Pluses ($^{+}$) and minuses ($^{-}$) represent model coefficient 95% confidence intervals outside and greater ($^{+}$) or less ($^{-}$) than the 95% confidence interval for the all-treatments model coefficients. There were 960 observations included in the "all treatments" model and 60 observations for each specific treatment combination model.

Treatment Combination	Intercept	Temp	VWC	Temp*VWC	Temp^2	VWC^2	r^2
All Treatments	**-3.90(±0.970)**	**0.243(±0.031)**	**8.89(±2.26)**	**1.81(±0.322)**	**0.004(±0.003)**	**-36.6(±20.1)**	0.422
B I CT H	0.774(±3.58)$^{+}$	**0.208(±0.110)**	-2.29(±7.32)$^{-}$	1.51(±1.56)	-0.010(±0.015)	**-101(±60.5)**	0.397
B I CT L	2.24± (4.02)$^{+}$	0.099(±0.122)	0.714(±8.09)	1.25(±1.75)	**-0.021(±0.016)**$^{-}$	8.44(±79.1)	0.340
B I NT H	**-4.61(±4.42)**	**0.288(±0.125)**	5.69(±9.67)	**2.98(±1.59)**	**0.018(±0.015)**	-47.1(±83.6)	0.611
B I NT L	**-5.32(±4.77)**	**0.306(±0.138)**	7.60(±9.42)	**2.71(±1.70)**	0.013(±0.016)	-81.5(±88.7)	0.534
B DL CT H	**-4.34(±4.00)**	**0.218(±0.122)**	**13.9(±9.88)**	**1.60(±1.15)**	0.003(±0.013)	-64.0(±81.5)	0.432
B DL CT L	-5.23(±5.34)	**0.216(±0.158)**	**15.9(±13.7)**	**3.64(±1.69)**	0.008(±0.016)	92.2(±112)	0.605
B DL NT H	**-3.17(±2.80)**	**0.137(±0.081)**	**7.80(±6.95)**	0.946(±0.930)	0.005(±0.011)	**68.5(±55.3)**$^{+}$	0.574
B DL NT L	-3.75(±4.92)	0.127(±0.142)	**16.4(±11.9)**	**2.35(±1.53)**	-0.001(±0.015)	**141.6(±114)**$^{+}$	0.562
NB I CT H	**-6.26(±5.34)**	**0.482(±0.180)**$^{+}$	-2.27(±11.1)	0.285(±2.30)	**0.023(±0.021)**	-101(±108)	0.436
NB I CT L	**-5.42(±4.95)**	**0.402(±0.161)**	-0.225(±11.7)	**2.52(±2.07)**	**0.022(±0.019)**	-36.1(±99.2)	0.530
NB I NT H	**-4.82(±3.21)**	**0.365(±0.124)**	-0.986(±6.54)$^{-}$	-0.335(±1.49)$^{-}$	0.009(±0.016)	-13.8(±63.7)	0.547
NB I NT L	-2.84(±4.07)	**0.362(±0.149)**	-8.81(±10.5)$^{-}$	-0.172(±1.99)	0.011(±0.020)	-12.2(±105)	0.397
NB DL CT H	**-4.16(±3.18)**	**0.188(±0.100)**	**16.0(±13.0)**	**1.69(±1.19)**	0.002(±0.012)	44.6(±92.1)	0.602
NB DL CT L	**-5.24(±4.90)**	**0.179(±0.153)**	**21.7(±14.0)**	**1.97(±1.55)**	0.001(±0.015)	109(±150)	0.491
NB DL NT H	**-4.28(±3.61)**	**0.189(±0.115)**	**14.6(±9.29)**	**2.00(±1.42)**	0.003(±0.016)	42.9(±101)	0.625
NB DL NT L	-2.60(±2.76)	**0.146(±0.081)**	**10.3(±6.45)**	**0.921(±0.901)**	-0.007(±0.011)	29.7(±59.1)	0.580

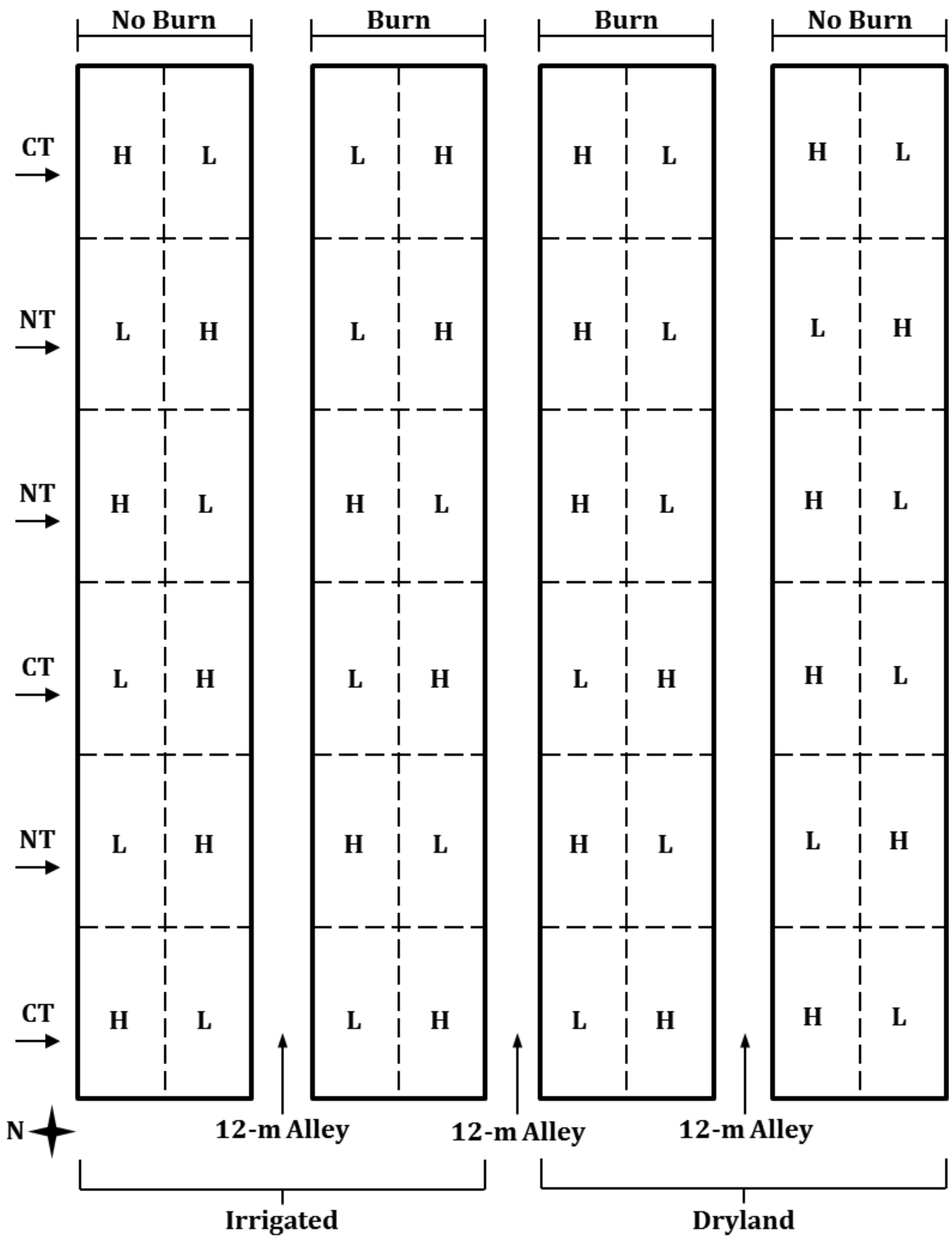

Fig. 1. Schematic diagram of the experimental layout at the Lon Mann Cotton Branch Experiment Station near Marianna in eastern Arkansas. High fertility (H), low fertility (L), conventional tillage (CT), and no-tillage (NT) residue treatments are shown. Individual plots are 3- by 6-m and the entire study area is a little over 0.5 ha

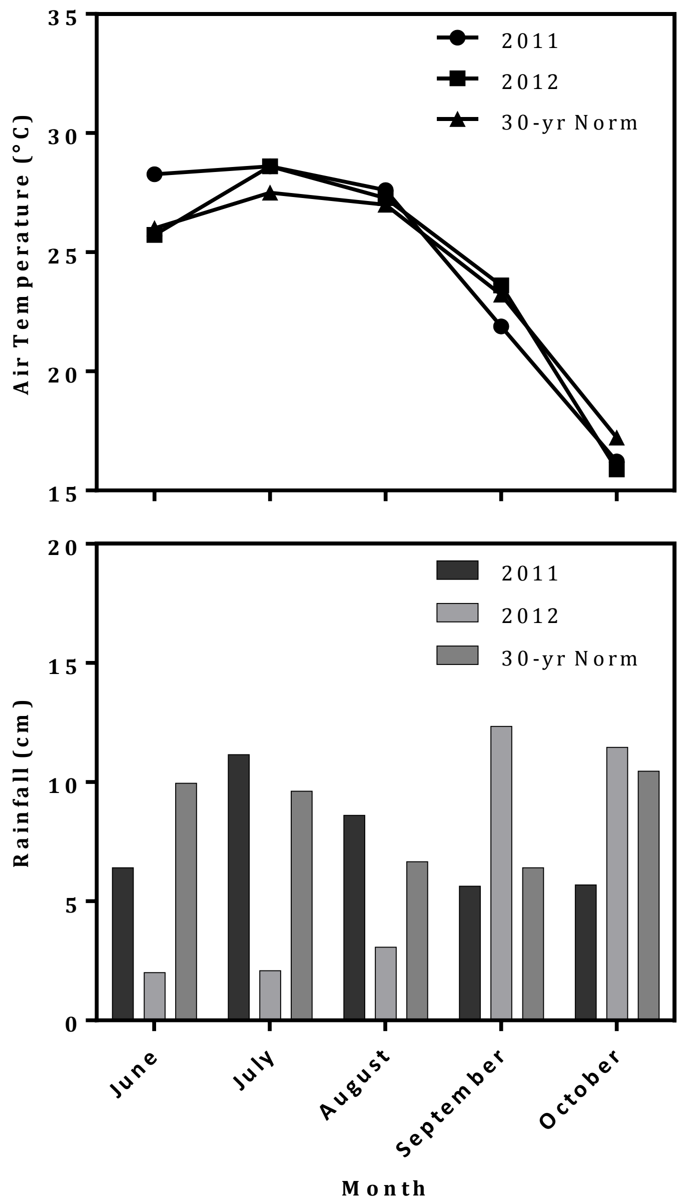

Fig. 2. Monthly average air temperatures and monthly rainfall amounts throughout the 2011 and 2012 soybean growing season and the 30-yr monthly normals for years 1981 to 2010 as measured from a weather station at the experimental location near Marianna, AR.

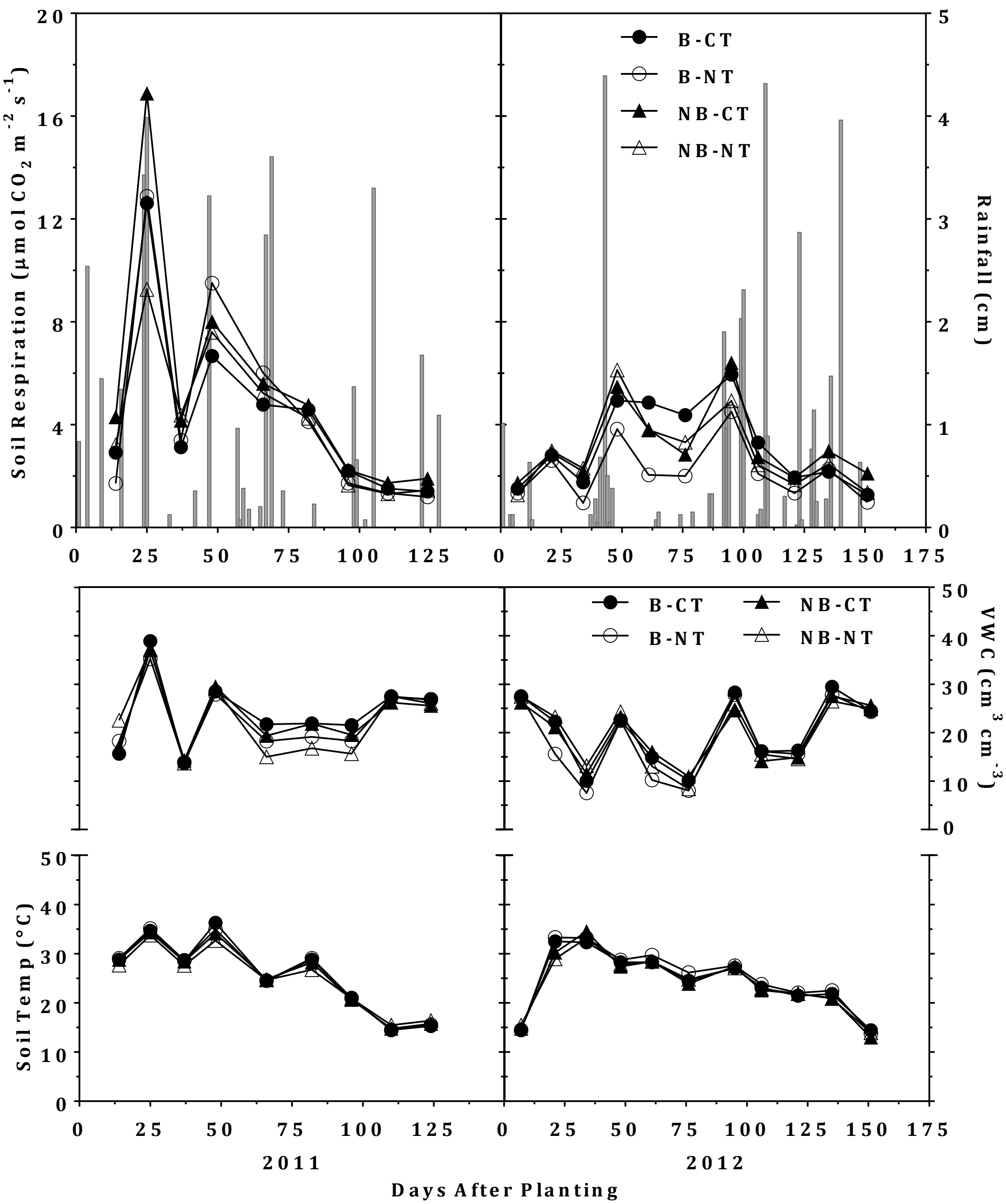

Fig. 3. Soil respiration as affected by similar burning-tillage treatment combination means for residue burning [burning (B) and non-burning (NB)] and tillage [conventional (CT) and no-tillage (NT)]. Corresponding 2-cm soil temperature (Temp) and 0- to 6-cm volumetric water content (VWC) are also plotted. Least significant differences (LSD) to compare soil respiration rates between treatment combinations and among sample dates depended on the combinations being compared and ranged from 1.05 to 3.57 µmol CO_2 m^{-2} s^{-1}.

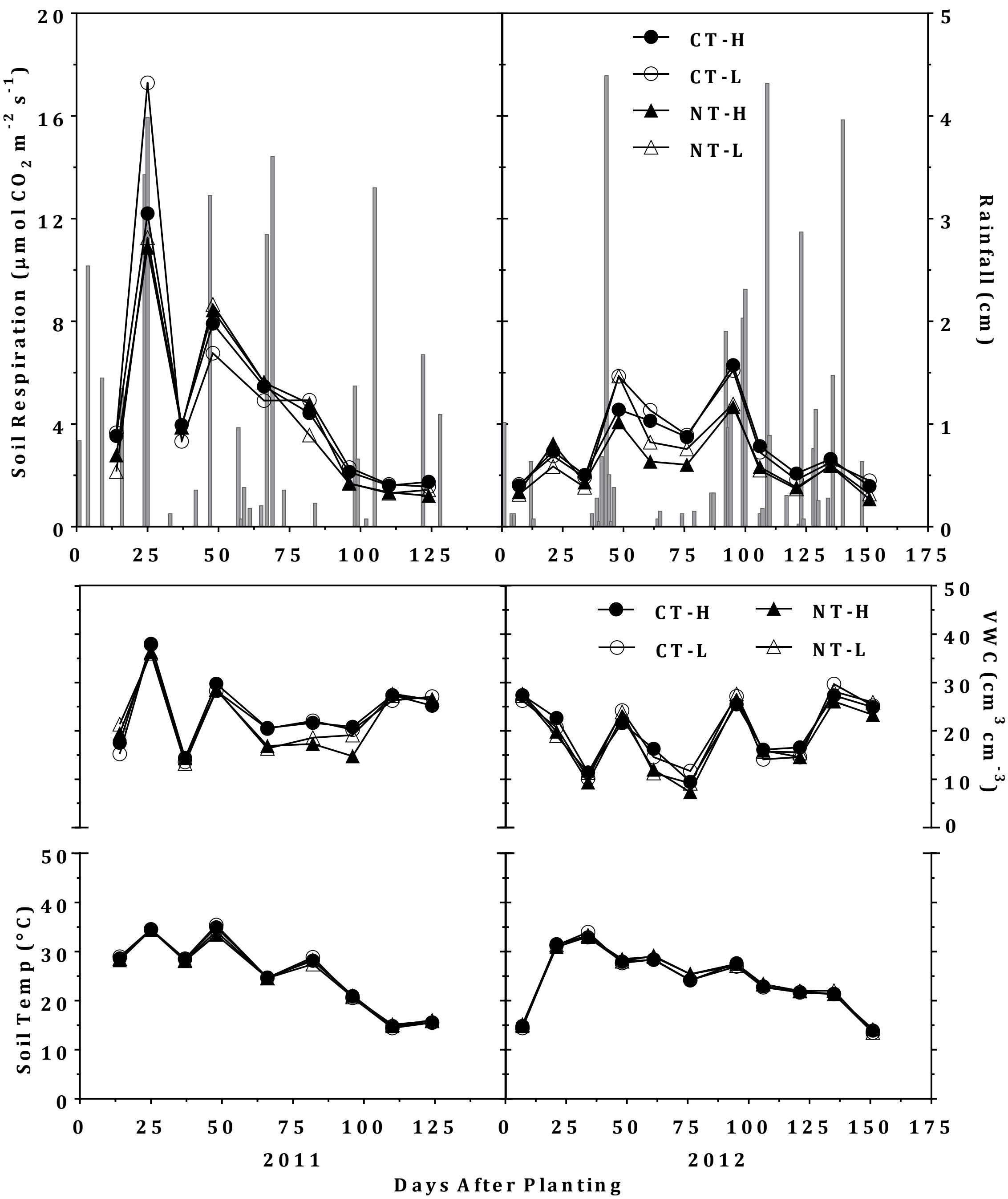

Fig. 4. Soil respiration as affected by similar tillage-residue treatment combination means for tillage [conventional (CT) and no-tillage (NT)] and residue level [high (H) and low (L)]. Corresponding 2-cm soil temperature (Temp) and 0- to 6-cm volumetric water content (VWC) are also plotted. Least significant differences (LSD) to compare soil respiration rates between treatment combinations and among sample dates in 2011 depended on the combinations being compared and ranged from 1.61 to 1.89 μmol CO_2 m^{-2} s^{-1}.

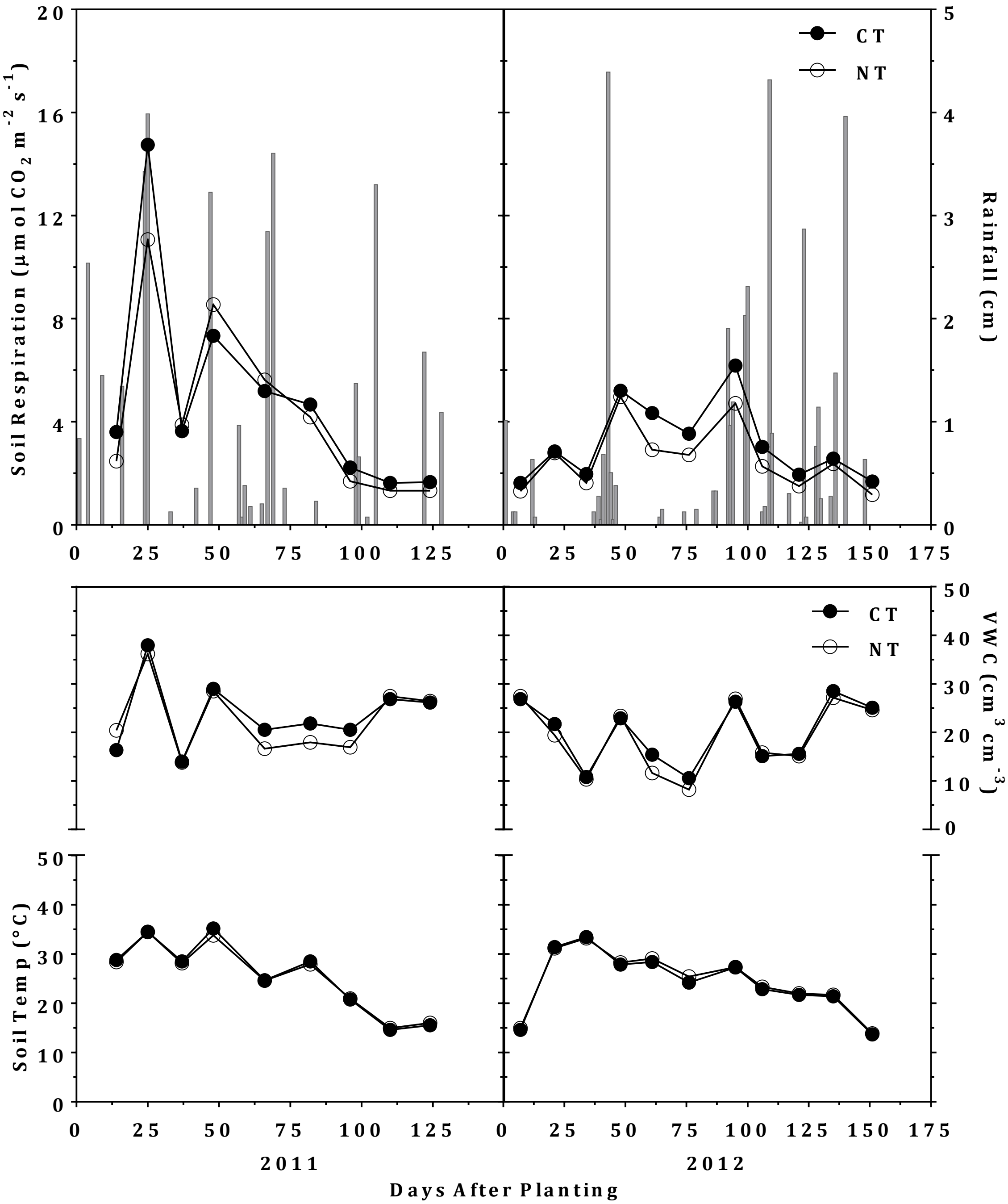

Fig. 5. Soil respiration as affected by tillage treatment [conventional (CT) and no-tillage (NT)]. Corresponding 2-cm soil temperature (Temp) and 0- to 6-cm volumetric water content (VWC) are also plotted. Least significant differences (LSD) to compare soil respiration rates between treatment combinations and among sample dates in 2012 depended on the combinations being compared and ranged from 0.57 to 0.58 µmol CO_2 m^{-2} s^{-1}.

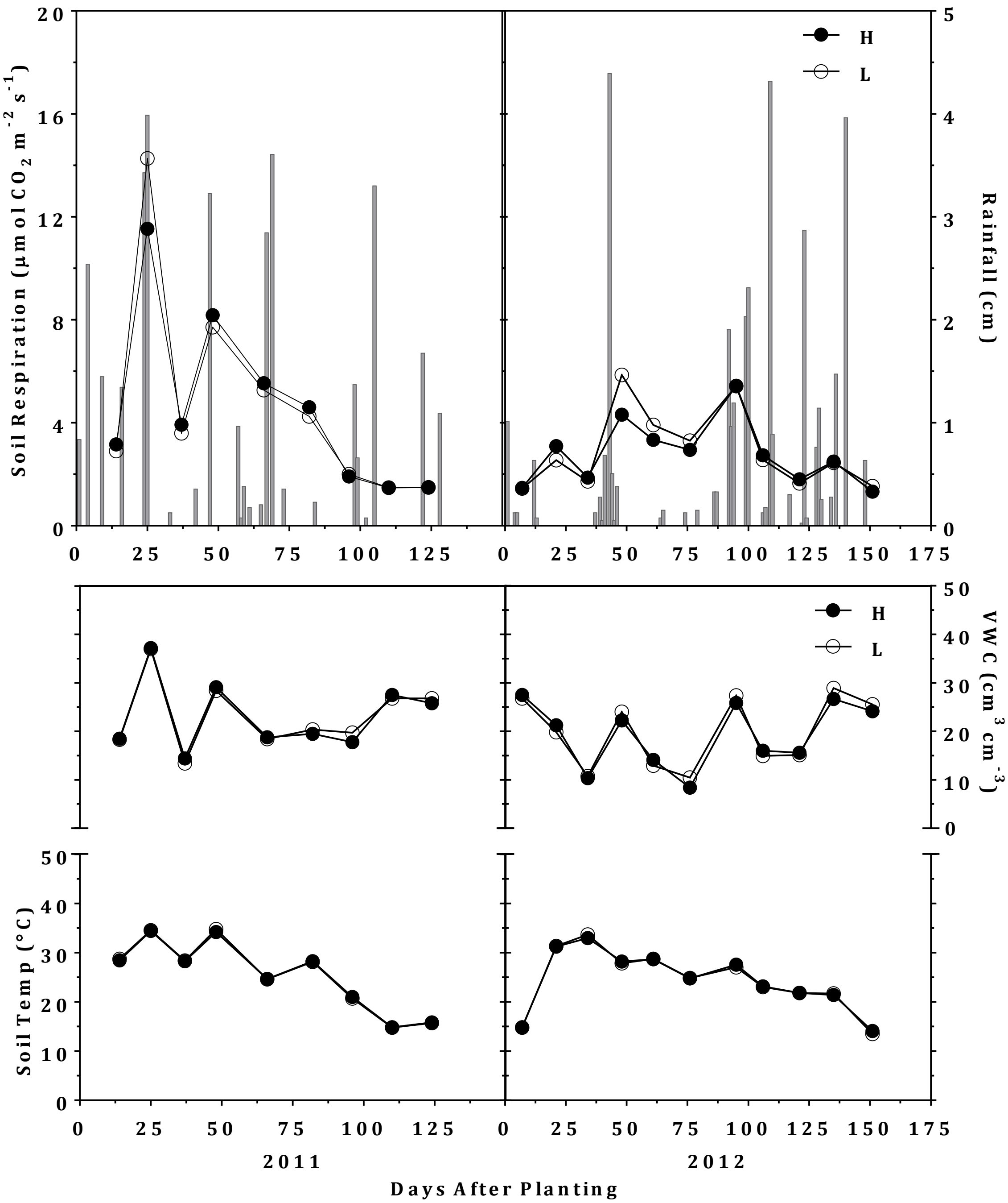

Fig. 6. Soil respiration as affected by residue-level treatment [high (H) and low (L)]. Corresponding 2-cm soil temperature (Temp) and 0- to 6-cm volumetric water content (VWC) are also plotted. Least significant differences (LSD) to compare soil respiration rates between treatment combinations and among sample dates in 2012 depended on the combinations being compared and ranged from 0.68 to 0.85 µmol CO_2 m^{-2} s^{-1}.

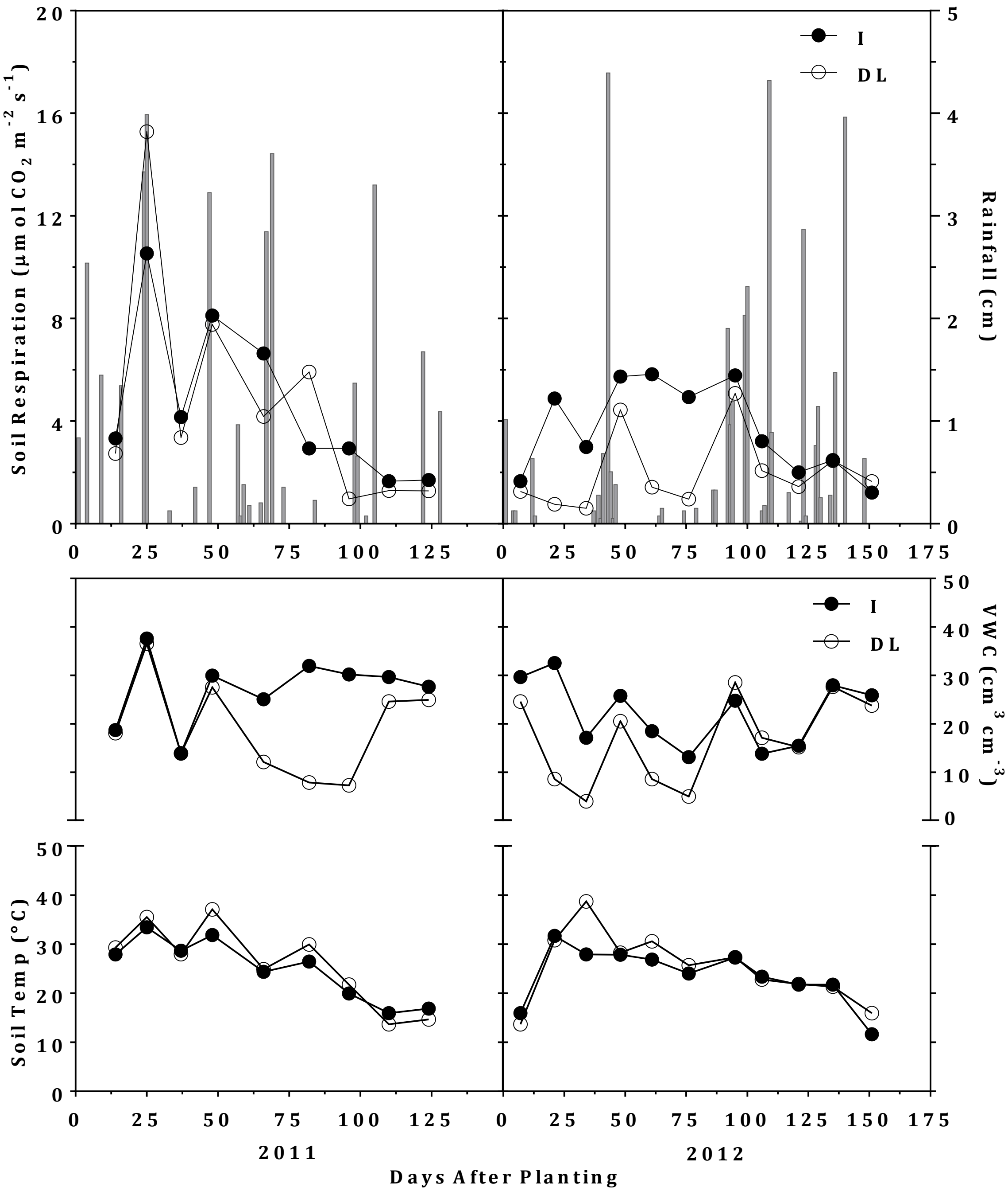

Fig. 7. Soil respiration as affected by irrigation treatment [irrigated (I) and dryland (DL)]. Corresponding 2-cm soil temperature (Temp) and 0- to 6-cm volumetric water content (VWC) are also plotted. Least significant differences (LSD) to compare soil respiration rates between treatment combinations and among sample dates in 2012 depended on the combinations being compared and ranged from 1.03 to 5.69 µmol CO_2 m^{-2} s^{-1}.

Chapter 3

Residue and Water Management Effects on Aggregate Stability and Associated Carbon and Nitrogen in a Wheat-soybean, Double-crop System

Abstract

Agricultural sustainability rests on the principle that agriculture must meet the needs of the present population while protecting the ability of future generations to meet their needs. Soil sustainability in agriculture is paramount to assuring continued production and land use of our most naturally fertile soils. Soil structure and carbon (C) storage can be influenced by a producer's choices regarding water- and residue-management techniques. The objective of this study was to evaluate the long-term effects of alternative residue (i.e., tillage, residue burning, and fertility) and water management (irrigated and dryland) practices after nine years of consistent management on total water-stable macroaggregate (> 0.25 mm) concentrations, size distributions, and corresponding C and nitrogen (N) concentrations in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern Arkansas. Total (TWSA) and size-separated water-stable aggregate (WSA) concentrations were affected by irrigation, tillage, fertility, and depth ($P < 0.05$). Total WSA concentration was not always negatively impacted by conventional tillage. Total WSA concentrations were 19% greater under CT than NT within the dryland-low-fertility treatment combination. High-fertility resulted in 18% less TWSA under high-fertility than low-fertility when compared within the irrigated-NT treatment combination, despite greater residue levels produced within the high-fertility treatment. Fertility also affected TWSA in different depths, depending on the water management practice used; under high-fertility, TWSA concentrations were 13% less in the lower depth (5- to 10-cm) under irrigation and were 10% less in the top 5 cm under dryland management when compared to the low-fertility treatment. When separated into class sizes, the smallest two size classes (0.25- to 0.5- and 0.5- to 1.0-mm) comprised over 80% of the total aggregates weighed. WSA concentrations of the largest two size classes (1- to 2- and >2-mm) were unaffected by all treatments imposed. Total and size-separated WSA C:N ratios were greater in the irrigated-high-fertility treatment than all other irrigation-fertility treatment combinations. Results of this study indicate that interactions between long-term management

practices can impact water-stable aggregation. Therefore, these findings are useful for determining long-term agricultural management practices that improve soil quality in eastern Arkansas.

Introduction

Soybean [*Glycine max* (L.) Merr.] is the second most planted field crop by acre in the United States, followed by corn. Over 31 million hectares of soybeans were planted in the United States in 2009, concentrated in the upper Midwest, although a large amount of soybeans are still planted in the southern region of the Mississippi River Delta. Arkansas ranks 8th nationally in total economic gain from soybean production in the United States. Arkansas produces the greatest amount of revenue of the three Delta states (i.e. Mississippi, Louisiana, Arkansas) from soybean production (UACES, 2000).

Soybean ranked second among the top agricultural commodities in Arkansas and soybean production is responsible for 16% of state farm receipts (USDA-ERS, 2013). Recently, 22% of soybeans grown in Arkansas were produced in a wheat (*Triticum aestivum* L.)-soybean, double-crop system, where winter wheat is planted the fall previous to the soybean crop (USDA-NASS, 2008). Producers have adopted this rotation an efficient way of increasing annual profits, while improving soil quality, since a double-crop system uses a winter cover crop that can provide income from a second annual cash crop. Other potential benefits from double-cropping include those that are often associated with cover crops, such as reduced incidence of pest problems (Bellinder et al., 2004), decreased erosion, increased organic matter (Reeves, 1997), and increased water-holding capacity (Dabney, 1998; Dabney et al., 2001).

The majority of Arkansas' row-crop land lies in the eastern part of the state, primarily in the Mississippi River Alluvial Plain, also referred to as the Arkansas Delta region (USDA-NASS, 2008). The Arkansas Delta Region is located in a humid sub-tropical climatic zone, where elevated moisture and temperature generally increase soil organic matter (SOM) decomposition and turnover rates. The average SOM concentration in the top 15 cm for the Arkansas Delta region is approximately 2.1% by loss-on-ignition (DeLong et al., 2003). Rapid turnover rates and relatively low SOM concentrations make soil structural stability and carbon (C) storage in the soil a major priority for soil and agricultural sustainability in the Arkansas Delta.

Aggregates or peds are groupings of soil separates and organic matter held more tightly to each other than the surrounding soil matrix. Aggregate stability is defined as the ability of an aggregate to withstand destructive forces such as tillage, raindrop impact, and erosion caused by wind and water (Kemper, 1986). Soils with increased aggregate stability have greater water infiltration rates and are less prone to losing nutrient-rich topsoil due to erosive forces (Marquez et al., 2004). Soil aggregates provide physical decomposition barriers for soil organic carbon (SOC), reducing the organic carbon's susceptibility to erosion and oxidation and consumption by soil biota (Wander and Bidart, 2000). Cultivation of land for agricultural purposes generally increases aggregate breakdown and decreases the total amount of stored C within the soil (Cambardella and Elliott, 1993).

A common disadvantage to double-cropping winter wheat with soybeans is the short growing season after wheat harvest for the soybean crop. This shortened growing season can limit the feasibility of double-cropping due to the potential negative impacts on soybean yield. Since wheat is typically harvested during late spring, soybean planting must be performed quickly since yield losses in the mid-south can occur if planting is postponed later than mid-June (Sanford, 1982). In order to rapidly deal with surface residue, prepare the seedbed, and reduce weed populations, many produces choose to quickly eliminate surface wheat residue by burning followed by tillage. Although some short-term benefits such as loose soil for soybean seeding and root growth, increased drainage and infiltration early in the season, increased soil aeration, reduce stratification of herbicides and nutrients in the soil, and weed and disease suppression, may come from these residue management practices (UACES, 2000), there is a growing number of studies that indicate such practices may reduce soil quality over time (Tisdall and Oades, 1982; Six et al., 2000; Chan et al., 2002; Malhi and Kutcher, 2007; Kasper et al., 2009; Anders et al., 2010).

The common management practices in the wheat-soybean double-crop production systems in eastern Arkansas generally include wheat fertilization in the early spring, burning of wheat residue after harvest, incorporation of residue by conventional tillage (CT), and irrigation of the subsequent soybean crop as needed throughout the season. Greater wheat residue at the soil surface and increased root biomass, induced by nitrogen (N) fertilization in the early spring, can increase the return of organic matter to the soil. Soil macroaggregate (> 0.25 mm-diameter aggregates) formation relies on the amount and stability of organic C in the soil (Tisdall and Oades, 1982; Six et al., 2000; Gillabel et al., 2007). Without stable organic matter, such as wheat straw and partially decomposed root biomass in the soil, macroaggregates can disintegrate to C-depleted microaggregates (< 0.25 mm-diameter aggregates; (Six et al., 2000).

Recently, the effects of using non-organic or mineral sources of N on soil quality and structure have come under some debate (Khan et al., 2007; Reid, 2008; Mulvaney et al., 2009; Powlson et al., 2010; Le Guillou et al., 2011). Some studies have shown a decrease in total soil C (Khan et al., 2007; Mulvaney et al., 2009) and a decrease in water-stable aggregation (Le Guillou et al., 2011) or little to no improvement of soil quality under mineral-N additions (Dapaah and Vyn, 1998; Mikha and Rice, 2004; Plaza-Bonilla et al., 2013), especially compared to the positive effects of organic-N additions over time. A metadata study involving data from 135 long-term (>10 yrs) studies showed that, although mineral-N additions do not actively decrease soil organic C and N over time, they do little to abate the negative effects of long-term cultivation on these soil properties (Churchman and Tate, 1986; Ladha et al., 2011).

Prior to tillage and soybean planting, wheat residue is commonly removed by burning. Burning not only removes surface residue, but also produces hydrophobic ash that can reduce infiltration and hinder aggregate formation (Wuest et al., 2005). Although burning may not have a dramatic effect on soil structure in the short-term (Wang et al., 2010), over long periods of time burning can reduce the overall C and N stored within the soil (Malhi et al., 2006; Wang et al., 2010) and reduce the soil structural stability, especially that of the larger macroaggregates (Chan et al., 2002). With new machinery capable of drill-seeding into standing wheat residue, producers now can practice greater soil conservation by using no-burn, no-tillage (NT) management practices.

Conventional tillage is well-recognized to cause decreased soil structural stability (Tisdall and Oades, 1982; Six et al., 2000; Kasper et al., 2009; Wang et al., 2010) and SOC and N (Cambardella and Elliott, 1993; Malhi et al., 2006; Malhi and Kutcher, 2007) over time. The breakdown rate from macro- to micro-aggregates is increased by CT, which results in a loss of total water-stable aggregates (Six et al., 2000). Mechanical disturbance by tillage breaks apart the protective barriers that encase sensitive particulate organic matter. Six et al. (2000) determined that CT can double the amount of macroaggregate breakdown and reduce the mean residence time of SOC by over 50% compared to NT practices. Once macroaggregates are broken apart and distributed throughout the plow layer, the younger and more labile C within becomes more accessible to soil biota (Cambardella and Elliott, 1993). Even reduced or minimal tillage practices can have a positive effect on soil structure and soil C storage (Kasper et al., 2009).

Aside from tillage, irrigation can be a major factor in the economic success of a crop, but little is known about the role irrigation plays in aggregate stability. The vast majority (79%) of soybean crops in Arkansas are irrigated (USDA-NASS, 2008). However, the sudden inundation of aggregates by furrow irrigation, the most common irrigation technique, can cause slaking to occur and unstable aggregates to disintegrate (Lehrsch et al., 2005). The most unstable, larger aggregates are more affected by slaking due to irrigation than the aggregates that are smaller in size (Six et al., 2000). An alternative water management practice to irrigation is dryland production (i.e. without irrigation). Dryland production is used when water is unavailable for the region or the cost of water is restrictive; however, the lack of water can cause a reduction or loss of yield from extended dry conditions. Although physical disturbances can occur with irrigation, availability of water during the growing season is likely to increase root and microbial biomass, which can decrease the negative impact of slaking on aggregate stability by increasing C stocks in the soil (Gillabel et al., 2007; Blanco-Canqui et al., 2010; Bhattacharyya et al., 2013).

Ensuring the long-term sustainability of soybean-producing soils in the Mississippi River Delta region is an ever-increasing issue for soybean producers in Arkansas. As groundwater sources become further depleted, fertilizer costs increase, and environmental perception and regulations become more severe, producers will need to look to alternative management practices that will promote the sustainability and cost-effectiveness of their land. However, switching to alternative management practices can be a risky endeavor for soybean producers. Knowing the potential long-term benefits of switching to alternative management practices can help producers make informed decisions. These long-term benefits cannot be determined from short-term studies, such as those that are less than three years in duration, as are many studies involving field crops. Some trends in environmental conditions may change over time. For instance, in a study conducted by Amuri et al. (2008) in a wheat-soybean double-crop system, the soil bulk density under NT increased at a greater rate than under CT for the first three years, but then bulk density under both NT and CT treatments decreased at a similar rate thereafter. If the study had only been conducted for three years, false conclusions might have been drawn regarding NT effects on soil bulk density.

In order to maintain long-term soil and agricultural sustainability in eastern Arkansas, a comprehensive study on how long-term water- and residue-management practices affect soil quality indicators, such as water-stable aggregates, is essential. Practices that increase the return of organic matter to the soil (high-fertility, no-burn, irrigation, and no-tillage) was hypothesized to increase the overall concentration of total water-stable aggregates (TWSA) and to promote the formation of aggregates with larger diameters. Irrigation, no-burn, no-tillage, and high-fertility treatments were expected to increase the amount of C and N contained within larger aggregate size classes. Since aggregate formation is largely driven by biological activity, the C:N ratios of water-stable aggregates were not expected to be affected by any treatment or treatment combination imposed. Little is known about the long-term interactive effects of irrigation, burning, tillage, and fertility management on aggregate stability and associated mineral concentrations, especially in the southern United States. Therefore, the objective of this study was to evaluate the long-term effects of alternative residue (i.e., tillage, residue burning, and residue level) and water management (irrigated and dry land) practices after nine years of consistent management on total water-stable macroaggregate (>0.25 mm) concentrations and size distributions as well as their corresponding C and N concentrations and C:N ratios in a wheat-soybean double-crop production system in the Mississippi River Delta region of eastern Arkansas.

Materials and Methods

Site Description

This study represents an extension of a long-term study that was initiated in Fall 2001 at the University of Arkansas' Lon Mann Cotton Research Station (N 34°, 44', 2.26" and W 90°, 45', 51.56"), near Marianna, in east-central Arkansas. The soil at the site is a Calloway silt loam (fine-silty, mixed, active, thermic Aquic Fraglossudalf; (NRCS, 2013). The top 10 cm of the soil profile is comprised of 16% sand, 73% silt, and 11% clay (Brye et al., 2007).

The 30-year mean annual temperature and precipitation in the region are 15.6°C and 128 cm, respectively (NOAA, 2002). The 30-year minimum and maximum air temperatures in the area are 2.4°C in January and 32.8°C in July, respectively (NOAA, 2002).

Treatments and Experimental Design

The study site consists of 48, 3- by 6-m plots (Fig. 1). Initially, from 2001 to 2005, field treatments consisted of only CT and NT, residue burning and no-burning, and high- and low-fertility levels (Cordell et al., 2007). The burn factor was arranged as a randomized complete block with two replications (Fig. 1). The tillage factor was a randomized complete block with three replications, stripped across burn treatments (Fig. 1). Different fertility levels were achieved by two different nitrogen (N) fertilizer application rates as a split-plot factor within each tillage-burn combination (Fig. 1). The entire study area was furrow-irrigated from 2001 through 2004. However, at the start of the 2005 soybean growing season, a water management treatment (irrigated or dryland) was added as a fourth factor with a similar blocking structure as burning, thus confounding the two factors (Fig. 1). Furthermore, the original experimental design was split in half to accommodate the new water management factor, resulting in a lack of replication for comparing burning-irrigation treatment combinations. This design allowed for six replications for every burning-tillage-fertility treatment combination or six replications for every irrigation-tillage-fertility treatment combination.

Field Management

Before the field study was initiated in 2001, the study site was used for soybean production under conventional tillage. In preparation for this field study, the site was disked twice and fertilized with a broadcast application of 20 kg N ha^{-1}, 22.5 kg P ha^{-1}, 56 kg K ha^{-1}, and 1120 kg ha^{-1} of pelletized limestone for pH adjustments (Cordell et al., 2007). Wheat was drill-seeded at a rate of 90 kg seed ha^{-1} with a 19-cm row spacing in early to mid-November each year (Brye et al., 2007). In early March 2002 through 2004, all plots were manually broadcast fertilized with 101 kg N ha^{-1} as urea (46% N). An additional 101 kg N ha^{-1} was applied in the high-residue plots at the late-jointing state of wheat growth in approximately late March. Due to excessive moisture in Fall 2004, no fertilizer-N was applied during Spring 2005. In 2006 and each year since, only the high-residue plots were manually broadcast fertilized with 56 kg N ha^{-1} as urea in late February to early March the following Spring. During the late-jointing stage, in approximately late March, wheat was fertilized again with a second application of 56 kg N ha^{-1} in the high-fertility plots only. Since 2006, low-fertility plots received no fertilization. Wheat was harvested with a plot combine in late May to early June each year.

Standing wheat residue was mowed to a height of 3- to 6-cm with a tractor-powered rotary mower in order to create a uniform surface layer of residue. Each year after mowing, the burn treatment was imposed by propane flaming. The tillage treatment was then imposed by disking two to three times to a depth of between 7-and 10-cm and then smoothed with a soil conditioner to break up soil clods.

A glyphosate-resistant soybean cultivar, maturity group 5.3 or 5.4, was drill seeded each year in approximately mid-June with a 19-cm row spacing at a rate of 47 kg seed ha^{-1}. Potassium (K) fertilizer was applied at recommended rates according to the University of Arkansas as needed. From 2005 to 2011, after soybean planting, a levee was established each year around the non-irrigated side to prevent water intrusion. Irrigated plots were furrow-irrigated as needed throughout the soybean growing season. Glyphosate was applied as needed, approximately once during the early soybean growing season and once more a month after planting. Soybeans were harvested with a plot combine between late October and early November. Each year any remaining soybean stubble was left standing and unmanipulated prior to planting the subsequent wheat crop.

Soil and Residue Sampling

Wheat Residue Levels

After the wheat was harvested and the standing stubble mowed in mid-June 2011, the amount of surface residue remaining on all plots was quantified by collecting all plant material from within a 0.5- by 0.5-m frame (0.25 m^2). Residue samples were oven-dried for 3-7 days at 55°C and weighed.

Soil Bulk Density

In August 2011, about 11 weeks after soybean planning and the day before aggregate sampling, a single 4.7-cm-diameter soil core was collected from the top 10 cm of each plot to assess treatment effects on soil bulk density. Soil samples were oven-dried at 70°C for 48 hours and weighed.

Soil Aggregate Stability

In late August 2011, two, 7.3-cm-diameter soil cores were collected from the top 10 cm of each plot using a core chamber and a slide hammer to assess the long-term effects of residue and water management practices on soil aggregate stability. The two cores were separated into 0-5- and 5-10-cm depths and combined for one composite sample per depth per plot. Field-moist soil samples were lightly hand crushed to pass through a 6-mm mesh screen. Samples were then air-dried for 7 days. Approximately 200 g of air-dried soil were used in a wet-sieving procedure described by Yoder (1936). Soil aggregates were repeatedly disturbed in water at 30 plunges per minute for 5 min in a mechanical wet-sieving apparatus and allowed to pass through a stack of progressively smaller sieves (i.e., 4-, 2-, 1-, 0.5-, and 0.25-mm mesh sizes). After plunging, soil aggregates remaining on each mesh screen were transferred to a drying tin, oven-dried at 70°C for 24 hr, and weighed separately by aggregate size. The two largest aggregate-class sizes (i.e. > 4- and 2- to 4-mm) were combined due to the lack of material to form a >2 mm class size. Total water-stable aggregates (TWSA) were calculated by summing the dry mass of soil aggregates retained on each of the five sieves and dividing by the original sample mass. After oven-drying and weighing, water-stable aggregate fractions were ground to pass through a 0.25-mm mesh screen for total C and N analyses. Size-separated, aggregate-N and –C concentrations were measured by high temperature combustion with an Elementar VarioMAX Total C and N Analyzer (Elementar Americas Inc., Mt. Laurel, NJ). The C:N ratios for each size class were calculated from the measured C and N concentrations. The largest aggregate size class (> 2 mm) did not have an adequate amount of material to perform C and N mineral analyses and was therefore not chemically analyzed. Un-sieved soil from each plot and sample depth was also oven-dried and ground to pass through a 0.25-mm mesh screen for bulk-soil C and N concentration analyses.

Data Analyses

Since the burning and irrigation treatment blocks were statistically confounded, two separate four-factor analyses of variance (ANOVAs) were initially performed based on a strip-split-split-plot design, each excluding one of the confounding factors, using the PROC GLM procedure in SAS (version 9.2, SAS Institute, Inc., Cary, NC) to evaluate the effects of burning/irrigation, tillage, fertility, soil depth, and their interactions on TWSA concentration and TWSA-associated C and N concentrations. Initial results demonstrated that burning main effect and all interactions including the burn treatment were non-significant ($P > 0.05$). Consequently, burning was the confounding factor that was removed from all subsequent statistical analyses. Total WSA C:N ratios and bulk-soil C and N concentrations and C:N ratios were subsequently analyzed in a similar manner as were TWSA concentration and TWSA-associated C and N concentrations. A five-factor ANOVA was conducted based on a strip-split-split-split-plot design using the PROC GLM procedure in SAS to evaluate the effects of irrigation, tillage, fertility, soil depth, aggregate-size class, and their interactions on WSA concentration among size classes and WSA-associated C and N concentrations and C:N ratios. As previously conducted (Brye et al., 2007), a three-factor ANOVA was conducted based on a strip-split-plot design using SAS to evaluate the effects of irrigation, tillage, fertility, and their interactions on wheat residue mass and soil bulk density. All treatment factors were considered fixed effects and blocks were treated as random effects in all analyses. When appropriate, means were separated using Fisher's protected least significant difference (LSD) at the $\alpha = 0.05$ level.

Results and Discussion

Water-stable Aggregation

Soil organic matter (SOM) contents of the Mississippi River Delta region of eastern Arkansas are relatively low due to a long history of cultivated agriculture in the region, with mean SOM and C contents of 0.21 g OM kg^{-1} and 1.12 g C kg^{-1}, respectively, in the top 12 cm of cropland soil (DeLong et al., 2003). Low levels of SOM and a relatively warm and wet climate promote rapid SOM turnover and subsequent soil C loss. The SOM content has long been considered an essential aspect of soil quality, which determines other aspects of soil function, such as water movement, nutrient status, plant growth effects, and erodibility (Magdoff and Weil, 2004). Soil aggregates provide physical barriers for soil organic carbon (SOC), reducing the organic C's susceptibility to erosion, oxidation and consumption by soil biota (Wander and Bidart, 2000). Soils with large inputs of organic material and reduced physical disturbance, such as those created with NT practices, typically have greater amounts of water-stable soil aggregates (Six et al., 2002). Therefore, it is important to understand how alternative management practices can affect WSA concentration and aggregate-size distribution of soils as, in general, the more SOM that is present in the soil the more fertile the soil will be in the long-term (Franzluebbers and Doraiswamy, 2007).

Water-stable Aggregation

After nine complete wheat-soybean cropping cycles in east-central Arkansas, TWSA concentration (g aggregates kg soil^{-1}; > 0.25 mm) in the top 10 cm was affected ($P < 0.05$) by all treatments evaluated in this study (i.e., irrigation, tillage, fertility, and soil depth). Specifically, TWSA concentrations differed among irrigation-tillage-fertility ($P = 0.037$) and among irrigation-fertility-depth combinations ($P = 0.028$; Table 1).

In the top 10 cm, TWSA concentration differed among tillage-fertility combinations within irrigation treatments. In the dryland-low-fertility treatment combination, TWSA concentration was 19% greater under CT (60.6 g kg^{-1}) than under NT (50.8 g kg^{-1}), but the effect of tillage was non-significant for all other irrigation-fertility treatment combinations (Fig. 2). Nitrogen-urea additions increase the amount and the decomposability of residue left on the soil surface from a wheat winter crop (Amuri et al., 2008). Wheat residue levels were 80.4% greater in the high-fertility treatment (8.3 Mg ha^{-1}) than the low-fertility treatment (4.6 Mg ha^{-1}) prior to soybean planting in this study ($P = 0.010$). It is possible that the reduction in residue, both from a mineral deficiency (low fertility) and from water-stressed conditions (no irrigation), caused a sub-optimal food stock for soil micro- and macroorganisims below the soil surface. Churchman and Tate (1986) reported a decrease in TWSA and soil C stocks after > 25 yr of irrigation in a seasonally dry New Zealand silt-loam soil, which was likely due to increased microbial decomposition when compared to dryland production. Although most studies have reported a decrease in TWSA and soil C under CT (Malhi and Kutcher, 2007; Yoo and Wander, 2008; Wang et al., 2010; Bhattacharyya et al., 2012, 2013), the incorporation of residue by CT in water-stressed conditions could have sustained a larger population of biota, thereby increasing the formation of exudates and organo-compounds that help stabilize aggregates.

Although TWSA concentration differed between tillage levels under dryland cropping, soil-bulk density, sampled the day prior, in the top 10 cm was unaffected ($P > 0.05$) by any treatment imposed and averaged 1.28 g cm^{-3} across the entire study area. The addition of urea-N in the high-fertility treatment reduced TWSA concentration by 18% (44.7 g kg^{-1}) compared to the low-fertility treatment (54.7 g kg^{-1}) within the irrigated-NT treatment combination; however, fertility did not affect TWSA concentrations in any other irrigation-tillage treatment combinations (Fig. 2).

The effects of mineral-N fertilization on SOM and TWSA has been under some debate during the last few years (Khan et al., 2007; Reid, 2008; Mulvaney et al., 2009; Powlson et al., 2010; Le Guillou et al., 2011; Plaza-Bonilla et al., 2013). In a laboratory experiment, Le Guillou et al. (2011) reported a significant decrease in TWSA in response to mineral-N additions to a soil previously amended with wheat straw compared to a soil with only straw additions. In addition, a concurrent increase in soil respiration was measured, indicating stimulation of microbial decomposition, which caused a subsequent loss of organic material in the high-N environment (Le Guillou et al., 2011). In the present study, above-ground residue was numerically greater (38%) under irrigation (6.5 Mg ha^{-1}) than under dryland production (4.7 Mg ha^{-1}). In addition, long-term CT practices significantly ($P < 0.05$) decreased the amount of above-ground residue by 30% (4.6 Mg ha^{-1}) compared to NT

(6.6 Mg ha^{-1}). As such, the irrigated-NT treatment combination had the greatest amount of C-rich surface residue that could be affected by mineral-N additions.

Within the high-fertility treatment, TWSA concentration was 22% greater in the dryland-CT (55.0 g kg^{-1}) than in the irrigated-NT treatment combination (44.7 g kg^{-1}; Fig. 2). In addition, irrigation did not affect TWSA concentrations under any other tillage-fertility treatment combination. In a long-term (>25yr) study in New Zealand, irrigation decreased TWSA in the top 5cm of a seasonally dry, silt loam (Churchman and Tate, 1986). The decrease in TWSA was proposed to be the effect of increasing decomposition rates of SOM by creating a more favorable environment for soil biota (Churchman and Tate, 1986). The addition of N to a soil with C-rich residue could have increased decomposition further within the irrigated-high-fertility treatment combination.

Total WSA concentrations also differed between fertility treatments within irrigation-depth treatment combinations. Although non-significant, TWSA concentrations were numerically greater by 11.9% in the non-irrigated (54.8 g kg^{-1}) than in the irrigated (48.9 g kg^{-1}) treatment when averaged over all other treatments (Fig. 3). Irrigation can lower TWSA concentrations in the near-surface soil by promoting microbial activity and decomposition of organic matter (Churchman and Tate, 1986), by causing slaking of aggregates due to the sudden inundation by flood irrigation (Lehrsch et al., 2005), or by the build-up of sodium ions from a contaminated water source (Sarig et al., 1993). Total WSA concentrations were consistently over 11% greater in the top 5 cm (57.1 g kg^{-1}) than in the 5- to 10-cm depth interval (46.5 g kg^{-1}) in all irrigation-fertility combinations. Generally, the top 5 cm of the soil has the greatest amount of SOM and biotic activity, thereby promoting a greater abundance and size of aggregates compared to lower depths (Anders et al., 2010). Furthermore, the greatest differences in TWSA concentration between soil depths were within the non-irrigated treatment (Fig. 3). The yearly addition of urea-N decreased the TWSA concentration by 13% in the 5- to 10-cm depth under irrigation (42.3 g kg^{-1}) and by 10% in the top

5 cm under dryland production (58.7 g kg^{-1}) compared to the same irrigation-depth combinations without urea-N additions (48.6 and 65.0 g kg^{-1}, respectively; Fig. 3). The negative effects of urea-N on TWSA in the 5- to 10-cm depth under irrigation and in the top 5 cm under dryland production may be reflective of the leaching of nitrate-N, a product of the nitrification of urea by bacteria, into greater depths of the soil profile (Bauder and Schneider, 1979).

The burning treatment, when analyzed in place of the confounding irrigation treatment, had no significant effect on TWSA concentrations ($P > 0.05$). Although some long-term experiments such as a 19-yr study in Australia by Chan et al. (2002) reported residue burning to be detrimental to soil aggregate stability (Wuest et al., 2005), others have reported little to no short term ($\leq$ 5 yr) effect on aggregation, aggregate-associated C, and aggregate-size distribution (Malhi and Kutcher, 2007; Wang et al., 2010). Malhi and Kutcher (2007) reported no significant effect of burning on soil-aggregate-size distribution in a 5-yr barley-canola rotation in Saskatchewan, Canada. Although tillage numerically reduced the mean weight diameter (MWD) of aggregates by 39%, there were no significant burning or tillage-burning treatment effects on MWD (Malhi and Kutcher, 2007). The effect of burning on water-stable aggregation may not be as pronounced in the short-term as the effects of irrigation or tillage, which cause a more immediate physical disturbance by slaking or mechanical disruption.

Water-stable Aggregate Size Distribution

When separated into four aggregate-size classes (i.e., 0.25- to 0.5-mm, 0.5- to 1.0-mm, 1.0- to 2.0 mm, and > 2.0 mm), the concentration of WSA (g aggregates kg $soil^{-1}$) was affected by all treatments evaluated in the study ($P < 0.05$; Table 2). Averaged across both depths, WSA concentrations differed among irrigation-tillage-fertility-size-class treatment combinations ($P < 0.001$; Table 2). Averaged across fertility treatments, WSA concentrations also differed among irrigation-tillage-depth-size-class combinations ($P = 0.025$; Table 2). In all irrigation-tillage-fertility and irrigation-tillage-depth combinations, WSA concentration decreased as aggregate-size class increased (Fig. 4 and 5). The lack of larger-diameter aggregates is to be expected in a cultivated soil which likely has a rapid rate of aggregate and C turnover (Six et al., 2000). Under irrigation and NT, urea-N additions in the high-fertility treatment reduced WSA concentrations by 23 and 20% in the 0.25- to 0.5- (21.3 g kg^{-1}) and 0.5- to 1.0-mm (13.3 g kg^{-1}) aggregate-size classes, respectively, compared to no urea-N additions for the low-fertility treatment (27.8 and 16.6 g kg^{-1}, respectively; Fig. 4). Similar to tillage effects on TWSA concentrations, CT reduced WSA concentrations by 13% in the 0.25- to 0.5-mm aggregate-size class within the irrigated-low-fertility treatment combination (24.1 g kg^{-1}), but increased WSA concentration of the same size class by 38% in the dryland-low-fertility treatment combination (32.3 g kg^{-1}) compared to the same irrigation-fertility treatment combinations under NT (27.8 and 23.4 g kg^{-1}, respectively).

Soil depth effects on WSA concentration among aggregate-class sizes were dependent on the tillage and irrigation treatments imposed (Table 2; Fig. 5). The WSA concentrations of the 0.25- to 0.5- and 0.5- to 1.0-mm aggregate-size classes were greater in the top 5 cm than in the 5- to 10-cm depth in all irrigation-tillage treatment combinations except for the irrigated-CT treatment combination (Fig. 5). Carbon lost as CO_2 during the 2011 and 2012 soybean growing season was numerically greater in the irrigated-CT treatment combination (642.5 g m^{-2}) than all other irrigation-tillage treatment combinations (< 554 g m^{-2}; Smith, 2013). This indicates a relatively quick aggregate and C turnover rate, which could be responsible for the larger macroaggregates being physically disintegrated into smaller aggregate-size classes. Under irrigation, the WSA concentration was 16% less under CT (24.0 g kg^{-1}) than NT (28.5 g kg^{-1}) in the 0.25- to 0.5-mm aggregate size class in the top 5 cm (Fig. 5). However, CT increased the WSA concentration by 24 and 17% in the same aggregate-size class in both the top 5 cm (35.2 g kg^{-1}) and the 5- to 10 cm depth (25.2 g kg^{-1}), respectively, under dryland production compared to the same irrigation-depth-size combinations under NT (28.5 and 21.5 g kg^{-1}, respectively; Fig. 5). The 1.0- to 2.0- and > 2-mm aggregate-size classes were unaffected by all irrigation, tillage, fertility and depth treatments imposed and averaged 0.42 and 9.5 g kg^{-1}, respectively.

Aggregate C and N Concentrations and C:N Ratios

Total Water-stable Aggregates

The TWSA C (g C kg aggregated $soil^{-1}$) and N (g N kg aggregated $soil^{-1}$) concentrations were affected by irrigation, depth, and tillage ($P < 0.05$; Table 1). Total WSA N concentrations were also affected by fertility ($P = 0.032$), while TWSA C concentrations were unaffected by fertility (Table 1). Total WSA C:N ratios were affected by irrigation, fertility and depth ($P < 0.05$; Table 1). Specifically, TWSA C:N ratios differed among irrigation-fertility treatment combinations ($P = 0.003$; Table 1) and among fertility-depth treatment combinations ($P = 0.021$; Table 1).

Total WSA C concentrations (g C kg $TWSA^{-1}$) differed among irrigation-depth ($P = 0.028$) and tillage-depth ($P = 0.009$) treatment combinations (Table 1). Total WSA C concentration under dryland production (23.9 g kg^{-1}) was numerically lower, but not significant, than under irrigation (28.2 g kg^{-1}) when averaged over both depths (Fig. 6). Under both irrigation and dryland production, TWSA C concentrations in the top 5 cm (34.5 and 28.0 g kg^{-1}) were 58 and 41% greater than in the 5- to 10-cm depth interval (21.9 and 19.9 g kg^{-1}, respectively), respectively (Fig. 6). These results are possibly due to the increased SOM and microbial activity in the top 5 cm of the soil profile (Anders et al., 2010).

Total WSA C and N concentrations differed similarly among tillage-depth treatment combinations ($P = 0.009$ and 0.004, respectively; Table 1). Nine years of CT decreased TWSA C and N concentrations in the top 5 cm (27.9 and 2.7 g kg^{-1}) by 20 and 16%, respectively, compared to NT (34.7 and 3.1 g kg^{-1}); however, CT increased the TWSA C and N concentrations in the 5- to 10-cm depth interval (22.7 and 2.1 g kg^{-1}) by 19 and 22%, respectively, compared to NT (19.1 and 1.7 g kg^{-1}; Fig. 7). Mechanical mixing of C- and N-rich organic matter and residues from the soil surface due to CT practices likely resulted in the relative decrease in the top 5 cm and increase in the 5- to 10-

cm depth compared to NT (Six et al., 2000). Total WSA C and N concentrations in the top 5 cm were consistently between 23 and 82% greater than in the 5- to 10-cm depth interval among tillage-depth treatment combinations (Fig. 7).

Total WSA N concentrations were also affected by irrigation and fertility (P = 0.041 and 0.032, respectively; Table 1). Averaged over all other treatment combinations, the TWSA N concentration under irrigated cropping (2.59 g kg^{-1}) was 15% greater than under dryland cropping (2.25 g kg^{-1}). Compared to the low-fertility treatment (2.33 g kg^{-1}), the yearly addition of urea-N to produce different levels of wheat residue in the high-fertility treatment increased TWSA N concentration by 8% (2.51 g kg^{-1}) when averaged over all other treatment combinations.

Total WSA C:N ratios differed among irrigation-fertility treatment combinations (P = 0.003; Table 1). Under irrigation, the TWSA C:N ratios was 6.2% less in the high- (1.6) than the low-fertility treatment (11.3; LSD = 0.29; Fig. 8). Low levels of available N during wheat production could have resulted in wheat residue with a greater C:N ratio in the low-fertility treatment. Soil mineral-N availability has been shown to increase the bioavailability of high C:N ratio residues, such as wheat straw and aggregate-binding agents (Le Guillou et al., 2011). When decomposition of complex carbon molecules becomes N-limited, substances that bind aggregates together are more difficult to break down and thus less vulnerable to microbial attack. Total WSA C:N ratios did not differ between irrigation treatments within the same fertility treatment (LSD = 6.77).

The C:N ratio of TWSA also differed among fertility-depth treatment combinations (P = 0.021; Table 1; Fig. 9). Within the 5- to 10-cm depth, TWSA C:N ratio under the high-fertility treatment (10.6) was 4.8% less than under the low-fertility treatment (11.1; LSD = 0.48; Fig. 9); however, there were no differences between fertility treatments in the top 5 cm were significant. Unexpectedly, there were differences among depths within the low-fertility treatment but not within the high-fertility treatment. Total WSA C:N ratio was 3.7% greater in the 5- to 10-cm depth (11.1) than in the top 5 cm (10.7) under the low-fertility treatment (LSD = 0.48; Fig. 9).

Water-stable Aggregates by Size Class

Although the WSA concentration of four aggregate-size classes were measured, the amount of material collected for the largest aggregate size (i.e. >2 mm) was inadequate for C and N analyses and was therefore left out of the subsequent WSA C and N analysis. Separated among three aggregate-size classes (i.e., 0.25- to 0.5-mm, 0.5- to 1.0-mm, and 1.0- to 2.0-mm), WSA C and N concentrations differed among tillage-depth-size class combinations ($P < 0.001$ and $P = 0.002$, respectively; Table 2). Water-stable aggregate N concentrations also differed among irrigation-fertility-depth-size class combinations ($P = 0.048$; Table 2). The C:N ratio among size-separated WSA was affected by the irrigation-fertility and the irrigation-tillage-size treatment imposed ($P < 0.05$; Table 2).

The C concentration of size-separated WSA differed among tillage-depth-size class combinations ($P < 0.001$; Table 2). The 5- to 10-cm depth interval contained 35% less WSA C (19.6 g kg^{-1}) than in the top 5 cm (30.1 g kg^{-1}) across all tillage-size class treatment combinations (Fig. 10). Nine years of CT decreased WSA C concentrations in the 0- to 5-cm depth interval among all size classes (Fig. 10). Mechanical disturbance of soil aggregates likely exposes the more labile C within the aggregate to possible microbial consumption that may cause a subsequent loss of C (Six et al., 2000). In contrast, CT increased WSA C by 26% in the 0.5- to 1.0-mm size class in the 5- to 10-cm depth interval (23.7 g kg^{-1}) compared to NT (18.8 g kg^{-1}; Fig. 10). Six et al. (2000) reported longer residence times, and hence older C sources, with decreasing aggregate-size class. Conventional tillage likely increased the amount of young C within the 5- to 10-cm depth of this study, thereby providing more C to form macroaggregates within the 5- to 10-cm than in the same depth interval under NT. Water-stable aggregate C concentrations typically decreased as aggregate-size class increased; however, WSA C concentration was greater in the 0.5- to 1.0-mm (34.9 g kg^{-1}) than in the 0.25- to 0.5 size class (31.7 g kg^{-1}) in the 0- to 5-cm depth interval (Fig. 10). Although many have reported increased WSA C concentrations with increasing aggregate-size class (Jastrow et al., 1996; Six et al., 2002; Yoo and Wander, 2008; Kasper et al., 2009), Anders et al. (2010) reported that the greatest WSA-C concentrations in a silt-loam soil were in the 1- to 2-mm and in the 0.5- to 1.0-mm aggregate-size classes in a 5-yr study in northern Arkansas.

Size-separated WSA N concentrations also differed among tillage-depth-size class combinations (P = 0.002; Table 2). Similar to WSA C concentrations, N concentrations in WSA in the 5- to 10-cm depth (1.8 g kg^{-1}) were, on average, 36% less than in the top 5 cm (2.8 g kg^{-1}; Fig. 10). In the top 5 cm, WSA N concentration did not differ between the 0.25- to 0.5-mm (2.8 g kg^{-1}) and the 0.5- to 1.0-mm (2.8 g kg^{-1}) class sizes under CT; however, the smaller two class sizes had a greater WSA N concentration than in the 1.0- to 2.0-mm class size (2.0 g kg^{-1}; Fig. 8). Water-stable aggregate N concentration in the top 5 cm was greatest in the 0.5- to 1.0-mm (3.5 g kg^{-1}) and smallest in the 1.0- to 2.0-mm (2.3 g kg^{-1}) aggregate-size class under NT (Fig. 10).

Nitrogen concentrations of size-separated WSA varied among irrigation-fertility-depth-size treatment combinations (P = 0.048; Table 2). Water-stable aggregate N concentrations were 14.8% greater under irritation and 19.3 % greater in both high- and low-fertility treatments , respectively, in the top 5 cm compared to that under dryland production (Fig. 11). Water-stressed conditions may have decreased N fixation by soybeans and reduced the amount of N build-up in the soil in both fertility treatments. In the low-fertility/5-10-cm treatment combination, WSA N concentration in the 0.5- to 1.0-mm aggregate-size class was also 22.7 % greater under irrigated (2.0 g kg^{-1}) compared to that under dryland production (1.6 g kg^{-1}; Fig. 11). The yearly addition of urea-N in the high-fertility treatment resulted in a greater WSA N concentration in the irrigated/5-10-cm treatment combination in the largest (1.0-2.0 mm; 1.54 g kg^{-1}) and smallest (0.25-0.5 mm; 2.55 g kg^{-1}) aggregate-size classes compared to that under the low-fertility treatment (Fig. 11).

Aggregate-size class and depth effects on WSA N concentration were dependent on the irrigation-fertility treatment combination imposed (Table 2). Size-separated WSA N concentrations were consistently greater, by an average of 54.4%, in the top 5 cm than in the 5- to 10-cm depth in the same irrigation-fertility-size treatment combination (Fig. 11). The WSA N concentration in the 5- to 10-cm was 46% less than in the 0- to 5-cm depth, under the low-fertility/1.0- to 2.0-mm size-class combination under both irrigation treatments (Fig. 11). Among all irrigation-fertility treatment combinations in the top 5 cm, WSA N concentration in the 1.0- to 2.0-mm size class (2.14 g kg^{-1}) was always approximately 34% less than in the remaining size classes (Fig. 11). Additionally, there were no differences in WSA N concentrations between the smallest two aggregate-size classes with one exception. In the top 5 cm, the 0.5- to 1.0-mm size class (3.5 g kg^{-1}) had a 2.2% greater WSA N concentration than in the 0.25- to 0.5-mm size class (3.2 g kg^{-1}) within the irrigated-low-fertility treatment combination (Fig. 11). Averaged over fertility and irrigation treatments in the 5- to 10-cm depth, WSA N concentrations in the 0.25- to 0.5-mm (2.2 g kg^{-1}) and the 0.5- to 1.0-mm (1.9 g kg^{-1}) size classes were 50 and 77% greater than in the 1.0- to 2.0-mm (1.3 g kg^{-1}) aggregate-size class, respectively (Fig. 11). Anders et al. (2010) also reported a decrease in WSA N concentrations with larger aggregate-size classes. Reduced WSA N and C concentrations in larger aggregate size classes may indicate a deficiency in relatively new organic matter in the soil. Six et al. (2000) suggested that macroaggregate (> 0.25 mm) formation is dependent on new organic matter additions in the soil, which is the reason why macroaggregates are more sensitive to changes in management practices than microaggregates that are formed from organic matter originating decades prior.

Similar to the TWSA C:N ratio, the impact of the fertility treatment on WSA C:N ratios depended on the irrigation treatment imposed ($P = 0.004$; Table 2). Averaged across size class, tillage, and depth, the C:N ratio of WSA was 8.3% greater under low- (11.7) than high-fertility (10.8) management when irrigated, but WSA C:N ratio was unaffected by fertility under dryland management (LSD = 0.42; Fig. 12). There were no significant differences between irrigation treatments within the same fertility treatment (LSD = 7.46).

Water-stable aggregate C:N ratios differed among size classes and were dependent on tillage and irrigation treatments ($P = 0.028$; Table 2). The C:N ratio of WSA generally increased with increasing size-class diameter when under irrigation, but the trend was much less noticeable under dryland management. Among all treatment combinations, the largest two aggregate-size classes had the greatest C:N ratios under the irrigated-tillage treatment combination (LSD = 0.50; Fig. 13). Water-stable C:N ratios did not differ between tillage treatments within the same irrigation-size-class combination (LSD = 0.57) or between irrigation treatments within the same tillage-size-class combination (LSD = 10.5). However, WSA C:N ratios were, on average, 4.7% greater under irrigated-NT (11.2) than dryland-CT (10.7) management combinations.

Bulk-soil C and N Concentrations and C:N Ratio

In addition to the size-separated aggregates, a portion of the un-sieved bulk soil from each sample in both depths was analyzed for their C and N concentrations. All treatments evaluated in this study impacted bulk-soil C and N concentrations ($P < 0.05$; Table 1). The C:N ratio of the bulk soil was affected by tillage and depth ($P = 0.046$), but was unaffected by irrigation and fertility treatments ($P > 0.05$; Table 1). The C ($P = 0.020$) and N ($P = 0.016$) concentrations of un-sieved bulk soil differed among irrigation-fertility treatment combinations (Table 1). The yearly addition of urea-N in the high-fertility treatment resulted in a 9% increase in both bulk-soil C (11.6 g kg^{-1}) and bulk-soil N (1.3 g kg^{-1}) concentrations under dryland cropping, while there was no effect of fertility under irrigated cropping (Fig. 14). Under dryland cropping, moisture levels may not have been optimal for extended periods for microbial decomposition of residue. Increased aboveground biomass of winter wheat from N-fertilization may not decompose as readily during the drier soybean growing season, thereby increasing bulk-soil C and N concentrations. However, under more optimal soil moisture conditions, mineral-N additions can decrease (Mikha and Rice, 2004; Khan et al., 2007; Mulvaney et al., 2009; Le Guillou et al., 2011) or cause little to no change (Dapaah and Vyn, 1998; Ladha et al., 2011) in bulk-soil C and N concentrations.

Bulk-soil C and N concentrations also differed (Table 1) among tillage-depth combinations in a similar manner as did TWSA C and N concentrations (Fig. 14). After 9 years of CT, bulk-soil C and N concentrations in the top 5 cm were 8 and 6% lower, respectively, than under NT (Fig. 14). It is well-documented that CT decreases bulk-soil C and N concentrations within the upper few centimeters of the soil (Six et al., 2000, 2002; Chan et al., 2002; Malhi and Kutcher, 2007; Anders et al., 2010). Not only does CT distribute the C and N from the OM-rich topsoil deeper into the soil profile, it causes organic matter to become more accessible and more easily consumed by soil biota by mixing and breaking up protective soil structures (Six et al., 2000). Similar to the effects of tillage on TWSA C and N concentrations, bulk-soil C (9.4 g kg^{-1}) and N (1.1 g kg^{-1}) concentrations were 22 and 18% greater, respectively, under CT in the 5- to 10-cm depth interval than under NT (7.7 and 0.9 g kg^{-1}, respectively; Fig. 14). Conventional tillage distributes C and N from the topsoil quickly to C and N depleted sub-soil. This causes an apparent increase in bulk-soil C and N at the lower depths under CT compared to NT, which tends to increase organic matter at the soil surface slowly over time (Potter et al., 1998).

Similar to bulk-soil C and N concentrations, bulk-soil C:N ratio also varied among tillage-depth treatment combinations ($P = 0.046$; Table 1). The bulk-soil C:N ratio was affected by tillage in the top 5 cm and was 10.5% greater than in the 5- to 10-cm depth. The bulk-soil C:N ratio was 1.5% greater under CT (9.3 g g^{-1}) than NT (9.5 g g^{-1}) in the top 5 cm (Fig. 15). Nitrogen depletion under CT likely demonstrates an increase in microbial degradation of SOM and incorporated residue. Correspondingly, season-long CO_2-C emissions were numerically smaller in the NT (577 and 403 g CO_2-C m^{-2}) than the CT (638 and 493 g CO_2-C m^{-2}) treatment in both 2011 and 2012, respectively, when averaged over all other treatments (Smith, 2013). Averaged over both tillage treatments, the top 5 cm (9.4 g g^{-1}) had an 11% greater bulk-soil C:N ratio than the 5- to 10-cm depth (8.5 g g^{-1}; Fig. 15). The C:N ratio difference between depths was greater under NT than CT and was likely an effect of slower decomposition of recalcitrant wheat residue left on the soil surface (Cambardella and

Elliott, 1993) as evidenced by numerically smaller mean CO_2-C emissions released under NT (490 g m^{-2}) during the 2011 and 2012 soybean growing seasons compared to CT (566 g m^{-2}; Smith, 2013).

In contrast to the TWSA and WSA C:N ratios, the bulk C:N ratio was unaffected by the irrigation-fertility treatment combination imposed ($P > 0.05$; Table 1), indicating that C and N concentrations in the bulk soil were affected similarly by irrigation and fertility treatments. These results suggest that the bulk-soil C:N ratio was not dependent on the aggregate-associated C:N ratio. Low concentrations of water-stable aggregates likely reduced the impact that changes in C and N dynamics in aggregates had on the bulk soil C and N concentrations.

Summary and Conclusions

This study demonstrated that, after 9 years of consistent residue management, total water-stable macroaggregates and associated size-class distributions were affected by all treatments evaluated. Contrary to what was hypothesized, irrigation negatively affected TWSA concentrations. Generally, TWSA concentrations were greater under dryland than irrigated management. However, irrigation can be absolutely essential to producing adequate yields to meet economic demands, especially in a wheat-soybean double-crop system. Although dryland production may not be an option under all circumstances and in all years, other types of irrigation systems or the manipulation of furrow size and water flow rates that allow water to slowly build up in the soil may help alleviate aggregate loss due to slaking.

Also contrary to what was hypothesized, TWSA and WSA concentrations were not always negatively affected by conventional tillage. In fact, TWSA and WSA concentrations were significantly greater under conventional tillage than no-tillage when paired with dryland and low-fertility treatments. There is a lack of literature on the interactive long-term effects of tillage, irrigation, and fertility treatments on soil physical properties, especially on aggregate stability.

Although greater amounts of wheat residue produced within the high-fertility than the low-fertility treatment, an overall reduction in TWSA concentration was observed within the high-fertility treatment. It was hypothesized that increased plant biomass return to the soil under the high-fertility treatment would positively influence WSA formation; however, the mineral-N additions could have caused an increase in microbial decomposition which negated the positive effects from greater residue return. This effect was more pronounced under irrigation than dryland production. Mineral-N additions may have increased aggregate-turnover rate by lowering the C:N ratio of the soil and providing more favorable conditions for microbial decomposition of organic material which binds aggregates together. However, no differences of soil C and N concentrations of the top 10 cm of the bulk soil among treatment combinations were detected prior to soybean planting. Therefore, any direct effects of mineral-N additions on soil biological function or increased aggregate turnover likely occurred during the wheat growing season. More studies on the effects of mineral-N additions on soil structure are needed to understand the long-term changes that may occur within this management system.

Overall, this long-term study indicated that irrigation and increased N can affect water-stable aggregation of soils in the Mississippi Delta region of eastern Arkansas. Additionally, there are interactive effects among water and residue management practices on soil structural stability that should be taken into consideration, such as the greater water-stable aggregation under CT than NT when paired with dryland and low-fertility management. Therefore, more evidence needs to be collected to determine the combined impact that these management practices have on the long-term sustainability of Arkansas' soil resource. The results from this study can contribute to the on-going effort to determine the best management practices for ensuring both short- and long-term productivity of United States agriculture.

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Appendices

Appendix 1: Example SAS program for strip-split-split analyses and relevant data files.
(Used for TWSA, bulk-soil properties with depth, ect.)

```
title 'Sharon Faye Smith: ANOVA FOR ALL RESP DATA (BY DATE)';
data Resp;
  infile 'RespDaily.csv' firstobs = 2 delimiter = ",";
  input plot tblock iblock bblock burn $ till $ irr $ fert $ year doy vwc wfps temp10 temp2 flux;
      label plot = 'Plot Number'
      tblock = 'Tillage Block'
      iblock = 'Irrigation Block'
                  bblock = 'Burn Block'
      till = 'Tillage'
      irr = 'Irrigation'
      fert = 'Nitrogen Level'
                  year = 'Sampling Year'
                  doy = 'Day of Year'
                  vwc = 'Vol Water Cont (cm3/cm3)'
                  wfps = 'Water Filled Pore Space (cm3/cm3 pore space)'
                  temp10 = 'Temp at 10cm'
                  temp2 = 'Temp at 2cm'
                  flux = 'Soil Respiration (umol CO2 m-2s-1)';
run;

proc glm data = Resp; where year=2011;
  class iblock tblock irr till fert doy;
  model flux =
                  irr
                  till
                  till*irr
                  fert
                  fert*irr
                  fert*till
                  fert*irr*till

                  doy
                  doy*irr
                  doy*till
                  doy*fert
                  doy*irr*till
                  doy*irr*fert
                  doy*till*fert
                  doy*irr*till*fert

                  iblock
                  tblock
                  iblock*irr
                  tblock*till
                  iblock*tblock*irr*till
```

```
              iblock*tblock*fert
              iblock*tblock*irr*fert
              iblock*tblock*till*fert
              iblock*tblock*irr*till*fert

              iblock*doy*irr
              tblock*doy*till
              iblock*tblock*doy*fert
              iblock*tblock*doy*irr*till
              iblock*tblock*doy*irr*fert
              iblock*tblock*doy*till*fert;
 random
              iblock
              tblock
              iblock*irr
              tblock*till
              iblock*tblock*irr*till
              iblock*tblock*fert
              iblock*tblock*irr*fert
              iblock*tblock*till*fert
              iblock*tblock*irr*till*fert

              iblock*doy*irr
              tblock*doy*till
              iblock*tblock*doy*fert
              iblock*tblock*doy*irr*till
              iblock*tblock*doy*irr*fert
              iblock*tblock*doy*till*fert / test;
quit;
```

plot	tblock	iblock	till	irr	fert	depth	twsa	ctwsa	ntwsa	cntwsa	C_bulk	N_bulk	CN_bulk
1	1	1	CT	I	H	1	38.3	30.6	2.94	10.41	12.62	1.33	9.52
2	1	1	NT	I	L	1	73.4	46.6	4.38	10.63	17.76	1.80	9.87
3	2	1	NT	I	H	1	50.2	40.3	3.74	10.77	12.86	1.37	9.40
4	2	1	CT	I	L	1	50.6	28.6	2.65	10.77	11.01	1.18	9.32
5	3	1	NT	I	L	1	53.2	29.8	2.56	11.64	11.43	1.27	9.00
6	3	1	CT	I	H	1	54.6	24.4	2.39	10.20	11.76	1.28	9.15
7	1	1	CT	I	L	1	40.8	41.8	3.64	11.46	14.41	1.51	9.55
8	1	1	NT	I	H	1	39.8	34.9	3.23	10.81	12.57	1.36	9.25
9	2	1	NT	I	L	1	75.2	33.0	3.16	10.45	15.41	1.70	9.08
10	2	1	CT	I	H	1	58.4	28.8	2.93	9.83	15.06	1.64	9.17
11	3	1	NT	I	H	1	61.3	33.7	3.23	10.45	13.19	1.48	8.94
12	3	1	CT	I	L	1	58.8	21.0	2.05	10.24	11.53	1.31	8.80
13	1	2	CT	I	L	1	37.7	39.5	3.20	12.34	11.43	1.28	8.94
14	1	2	NT	I	L	1	39.1	40.2	3.33	12.08	13.25	1.40	9.47
15	2	2	NT	I	H	1	47.7	42.1	3.53	11.94	12.72	1.31	9.68
16	2	2	CT	I	L	1	44.1	27.5	2.48	11.08	10.75	1.18	9.11
17	3	2	NT	I	H	1	63.4	36.4	3.40	10.69	13.31	1.39	9.54
18	3	2	CT	I	L	1	58.4	30.2	2.73	11.06	11.46	1.25	9.19
19	1	2	CT	I	H	1	34.4	38.1	3.32	11.47	12.29	1.30	9.48
20	1	2	NT	I	H	1	45.6	42.6	3.68	11.59	13.98	1.46	9.56
21	2	2	NT	I	L	1	55.0	39.5	3.48	11.37	13.73	1.41	9.74
22	2	2	CT	I	H	1	57.8	32.9	3.18	10.36	11.57	1.25	9.29
23	3	2	NT	I	L	1	62.1	37.5	3.40	11.02	13.63	1.41	9.65
24	3	2	CT	I	H	1	57.4	28.5	2.71	10.54	12.49	1.32	9.48
25	1	1	CT	NI	H	1	35.9	21.4	2.14	9.96	10.59	1.18	8.96
26	1	1	NT	NI	H	1	38.7	39.9	3.54	11.28	12.23	1.30	9.44
27	2	1	NT	NI	H	1	52.5	35.3	3.20	11.02	12.44	1.32	9.40
28	2	1	CT	NI	L	1	45.2	23.4	2.27	10.34	11.48	1.20	9.58
29	3	1	NT	NI	H	1	55.9	30.2	2.76	10.92	12.51	1.33	9.38
30	3	1	CT	NI	L	1	68.9	22.4	2.17	10.30	11.34	1.21	9.39
31	1	1	CT	NI	L	1	65.6	24.2	2.37	10.19	11.76	1.26	9.31
32	1	1	NT	NI	L	1	54.4	32.8	3.02	10.86	12.54	1.29	9.72
33	2	1	NT	NI	L	1	62.3	31.2	2.92	10.66	11.48	1.23	9.36
34	2	1	CT	NI	H	1	47.6	22.9	2.33	9.79	11.47	1.18	9.69
35	3	1	NT	NI	L	1	57.2	26.7	2.45	10.89	10.79	1.17	9.25
36	3	1	CT	NI	H	1	55.7	21.4	2.17	9.84	11.05	1.24	8.90
37	1	2	CT	NI	H	1	58.4	33.9	3.18	10.66	15.55	1.63	9.54
38	1	2	NT	NI	L	1	55.2	31.6	2.99	10.54	15.62	1.63	9.59
39	2	2	NT	NI	H	1	58.3	29.9	2.68	11.18	14.81	1.58	9.39
40	2	2	CT	NI	H	1	63.0	27.3	2.63	10.38	16.73	1.74	9.64
41	3	2	NT	NI	L	1	48.3	25.7	2.52	10.23	13.58	1.44	9.41
42	3	2	CT	NI	H	1	91.3	24.8	2.40	10.34	13.40	1.44	9.31

43	1	2	CT	NI	L	1	97.6	24.0	2.55	9.41	14.74	1.52	9.73
44	1	2	NT	NI	H	1	79.0	32.0	2.82	11.36	15.91	1.62	9.81
45	2	2	NT	NI	L	1	68.6	26.0	2.53	10.28	12.14	1.31	9.23
46	2	2	CT	NI	L	1	75.8	26.2	2.62	10.01	14.00	1.48	9.43
47	3	2	NT	NI	H	1	68.2	34.2	3.03	11.28	19.68	2.00	9.82
48	3	2	CT	NI	L	1	81.3	25.5	2.62	9.75	12.83	1.38	9.30
1	1	1	CT	I	H	2	35.4	31.6	3.46	9.13	9.04	1.04	8.67
2	1	1	NT	I	L	2	47.8	22.7	2.13	10.68	7.11	0.86	8.29
3	2	1	NT	I	H	2	35.8	20.1	1.66	12.07	6.09	0.77	7.92
4	2	1	CT	I	L	2	55.5	22.7	1.78	12.72	8.99	1.11	8.12
5	3	1	NT	I	L	2	64.7	24.0	2.27	10.57	10.34	1.19	8.71
6	3	1	CT	I	H	2	53.9	16.3	2.70	6.02	6.73	0.85	7.88
7	1	1	CT	I	L	2	34.7	24.9	1.98	12.54	8.89	1.07	8.28
8	1	1	NT	I	H	2	30.6	18.5	1.39	13.34	5.45	0.72	7.56
9	2	1	NT	I	L	2	59.7	21.7	2.03	10.70	8.03	1.00	8.05
10	2	1	CT	I	H	2	52.6	19.7	2.55	7.73	8.79	1.11	7.91
11	3	1	NT	I	H	2	48.2	14.1	1.29	10.97	6.65	0.85	7.84
12	3	1	CT	I	L	2	60.0	16.4	1.55	10.62	8.24	0.99	8.29
13	1	2	CT	I	L	2	31.6	27.4	2.27	12.10	9.41	1.05	8.96
14	1	2	NT	I	L	2	34.9	19.5	1.60	12.18	7.01	0.83	8.40
15	2	2	NT	I	H	2	37.2	25.0	2.06	12.13	6.58	0.78	8.49
16	2	2	CT	I	L	2	48.3	24.2	2.10	11.49	8.40	0.96	8.73
17	3	2	NT	I	H	2	43.7	17.6	1.80	9.77	6.82	0.83	8.19
18	3	2	CT	I	L	2	54.2	21.5	1.99	10.79	8.89	1.04	8.58
19	1	2	CT	I	H	2	33.1	30.0	2.40	12.53	10.23	1.16	8.85
20	1	2	NT	I	H	2	33.0	21.1	2.07	10.18	7.45	0.91	8.21
21	2	2	NT	I	L	2	41.1	19.9	1.71	11.64	7.16	0.87	8.24
22	2	2	CT	I	H	2	53.9	26.5	2.47	10.73	9.61	1.08	8.91
23	3	2	NT	I	L	2	50.3	20.7	1.83	11.28	7.39	0.91	8.15
24	3	2	CT	I	H	2	50.4	19.8	1.84	10.77	8.34	0.98	8.51
25	1	1	CT	NI	H	2	35.1	24.1	2.16	11.17	9.06	1.07	8.46
26	1	1	NT	NI	H	2	27.7	19.4	1.71	11.32	7.08	0.88	8.01
27	2	1	NT	NI	H	2	28.6	19.3	1.70	11.35	7.03	0.82	8.52
28	2	1	CT	NI	L	2	36.8	26.3	2.30	11.43	9.64	1.05	9.15
29	3	1	NT	NI	H	2	41.0	19.2	1.79	10.77	8.14	0.96	8.50
30	3	1	CT	NI	L	2	39.4	23.5	2.01	11.68	8.02	0.92	8.71
31	1	1	CT	NI	L	2	38.8	17.4	1.46	11.91	9.36	1.06	8.82
32	1	1	NT	NI	L	2	28.4	18.4	1.83	10.04	6.95	0.84	8.30
33	2	1	NT	NI	L	2	33.0	17.6	1.61	10.92	7.18	0.84	8.51
34	2	1	CT	NI	H	2	34.3	22.7	2.05	11.08	8.82	1.00	8.78
35	3	1	NT	NI	L	2	35.6	15.9	1.37	11.59	6.54	0.80	8.20
36	3	1	CT	NI	H	2	48.3	18.1	1.72	10.51	9.77	1.15	8.51
37	1	2	CT	NI	H	2	71.2	22.5	2.15	10.48	11.30	1.30	8.67

38	1	2	NT	NI	L	2	50.5	16.6	1.57	10.62	8.95	1.05	8.50
39	2	2	NT	NI	H	2	45.6	17.3	1.76	9.83	9.57	1.15	8.31
40	2	2	CT	NI	H	2	65.7	30.1	2.68	11.23	13.51	1.44	9.38
41	3	2	NT	NI	L	2	52.0	12.8	1.24	10.25	6.46	0.77	8.35
42	3	2	CT	NI	H	2	53.2	19.4	1.89	10.27	9.84	1.13	8.68
43	1	2	CT	NI	L	2	69.4	18.3	1.83	9.99	10.24	1.15	8.90
44	1	2	NT	NI	H	2	70.9	25.5	2.27	11.21	9.82	1.10	8.96
45	2	2	NT	NI	L	2	63.8	14.2	1.42	9.97	11.34	1.23	9.19
46	2	2	CT	NI	L	2	48.2	20.8	1.84	11.25	8.68	1.00	8.71
47	3	2	NT	NI	H	2	65.0	16.9	1.73	9.79	8.76	0.98	8.90
48	3	2	CT	NI	L	2	60.9	20.7	2.03	10.18	10.80	1.17	9.26

Appendix 2. Example SAS program for strip-split-split-split analyses and relevant data files.
(Used for size-separated water-stable aggregate concentrations and corresponding C and N concentrations and ratios)

```
title 'Sharon Faye Smith: WSA (with size separation) Irrigation as a main effect';
data Aggstsize;
  infile 'WSAwIrr - all response variables.csv' firstobs = 2 delimiter = ",";
  input plot tblock iblock till $ irr $ fert $ depth $ size aggconc cwsa nwsa cnwsa;
  label plot = 'Plot number'
        tblock = 'Tillage block'
        iblock = 'irr block'
        till = 'Tillage'
        irr = 'Irrigation'
        fert = 'Residue level'
        depth = 'Soil Depth'
        size = 'aggregate size class'
        aggconc = 'aggregate concentration (g/kg)'
              cwsa = 'WSA Carbon Concentration (g/kg)'
              nwsa = 'WSA Nitrogen Concentration (g/kg)'
              cnwsa = 'WSA C:N ratio (g C/g N)';
run;
quit;

title2 'Water Stable Aggregate Concentrations';

proc glm   data = Aggstsize;
  class tblock iblock till irr fert depth size;
  model aggconc =
             irr
             till
             till*irr
             fert
             fert*irr
             fert*till
             fert*irr*till
             Depth
             Depth*irr
             Depth*till
             Depth*fert
             Depth*irr*till
             Depth*irr*fert
             Depth*till*fert
             Depth*irr*till*fert
             Size
             Size*irr
             Size*till
             Size*fert
             Size*Depth
             Size*irr*till
             Size*irr*fert
```

```
        Size*irr*depth
        Size*till*fert
        Size*till*Depth
        Size*fert*Depth
        Size*irr*till*fert
        Size*irr*till*Depth
        Size*irr*fert*depth
        Size*till*fert*Depth
        Size*irr*till*fert*Depth
         tblock tblock*till   iblock iblock*irr      tblock*iblock*till*irr
         tblock*iblock*fert   tblock*iblock*till*fert  tblock*iblock*irr*fert   tblock*iblock*till*irr*fert
         tblock*depth*till      iblock*depth*irr   tblock*iblock*depth*fert
         tblock*iblock*till*irr   tblock*iblock*depth*till*fert  tblock*iblock*depth*irr*fert
         tblock*iblock*depth*till*irr*fert
         tblock*size*till iblock*size*irr tblock*iblock*size*fert
         tblock*size*depth*till iblock*size*depth*irr
         tblock*iblock*size*depth*fert tblock*iblock*size*till*irr tblock*iblock*size*till*fert
         tblock*iblock*size*irr*fert
         tblock*iblock*size*irr*till*fert tblock*iblock*size*depth*till*irr
         tblock*iblock*size*depth*till*fert
         tblock*iblock*size*depth*irr*fert;
 random
        tblock tblock*till   iblock iblock*irr      tblock*iblock*till*irr
         tblock*iblock*fert   tblock*iblock*till*fert  tblock*iblock*irr*fert   tblock*iblock*till*irr*fert
         tblock*depth*till      iblock*depth*irr   tblock*iblock*depth*fert
         tblock*iblock*till*irr   tblock*iblock*depth*till*fert  tblock*iblock*depth*irr*fert
         tblock*iblock*depth*till*irr*fert
         tblock*size*till iblock*size*irr tblock*iblock*size*fert
         tblock*size*depth*till iblock*size*depth*irr
         tblock*iblock*size*depth*fert tblock*iblock*size*till*irr tblock*iblock*size*till*fert
         tblock*iblock*size*irr*fert
         tblock*iblock*size*irr*till*fert
         tblock*iblock*size*depth*till*irr tblock*iblock*size*depth*till*fert
         tblock*iblock*size*depth*irr*fert / test;
quit;
```

plot	tblock	iblock	till	irr	fert	depth	size	aggconc	cwsa	nwsa	cnwsa
1	1	1	CT	I	H	1	1	0.00	44.07	1.85	23.86
1	1	1	CT	I	H	1	2	9.23	25.00	2.25	11.13
1	1	1	CT	I	H	1	3	11.56	36.46	3.40	10.72
1	1	1	CT	I	H	1	4	17.49	29.68	3.00	9.89
2	1	1	NT	I	L	1	1	0.00	76.01	2.48	30.60
2	1	1	NT	I	L	1	2	8.53	43.00	3.60	11.94
2	1	1	NT	I	L	1	3	19.11	63.87	5.74	11.12
2	1	1	NT	I	L	1	4	45.74	40.00	3.95	10.12
3	2	1	NT	I	H	1	1	1.00	36.96	1.91	19.36
3	2	1	NT	I	H	1	2	9.74	27.67	2.58	10.72
3	2	1	NT	I	H	1	3	13.62	47.20	4.20	11.23
3	2	1	NT	I	H	1	4	25.88	41.54	4.00	10.38
4	2	1	CT	I	L	1	1	0.46	55.87	2.67	20.92
4	2	1	CT	I	L	1	2	9.50	19.11	1.70	11.26
4	2	1	CT	I	L	1	3	13.14	34.56	3.07	11.26
4	2	1	CT	I	L	1	4	27.50	28.50	2.78	10.25
5	3	1	NT	I	L	1	1	0.75	76.01	2.48	30.60
5	3	1	NT	I	L	1	2	12.17	17.24	1.22	14.13
5	3	1	NT	I	L	1	3	15.03	29.70	2.56	11.59
5	3	1	NT	I	L	1	4	25.21	34.62	3.22	10.77
6	3	1	CT	I	H	1	1	0.62	44.07	1.85	23.86
6	3	1	CT	I	H	1	2	11.73	16.78	1.44	11.64
6	3	1	CT	I	H	1	3	17.80	23.48	2.37	9.91
6	3	1	CT	I	H	1	4	24.47	28.27	2.88	9.81
7	1	1	CT	I	L	1	1	0.69	55.87	2.67	20.92
7	1	1	CT	I	L	1	2	8.12	29.41	2.49	11.80
7	1	1	CT	I	L	1	3	10.28	54.85	4.50	12.18
7	1	1	CT	I	L	1	4	21.71	39.73	3.70	10.75
8	1	1	NT	I	H	1	1	0.00	36.96	1.91	19.36
8	1	1	NT	I	H	1	2	8.19	17.70	1.63	10.86
8	1	1	NT	I	H	1	3	10.38	41.65	3.53	11.78
8	1	1	NT	I	H	1	4	21.27	38.28	3.70	10.35
9	2	1	NT	I	L	1	1	0.69	76.01	2.48	30.60
9	2	1	NT	I	L	1	2	12.27	23.72	2.30	10.32
9	2	1	NT	I	L	1	3	22.65	37.39	3.56	10.50
9	2	1	NT	I	L	1	4	39.60	32.63	3.21	10.18
10	2	1	CT	I	H	1	1	0.00	44.07	1.85	23.86
10	2	1	CT	I	H	1	2	9.88	17.69	1.64	10.79
10	2	1	CT	I	H	1	3	17.36	33.76	3.28	10.29
10	2	1	CT	I	H	1	4	31.21	29.57	3.14	9.41
11	3	1	NT	I	H	1	1	0.00	36.96	1.91	19.36
11	3	1	NT	I	H	1	2	12.47	18.78	1.95	9.63

11	3	1	NT	I	H	1	3	17.43	37.58	3.43	10.94
11	3	1	NT	I	H	1	4	31.38	37.49	3.62	10.36
12	3	1	CT	I	L	1	1	0.35	55.87	2.67	20.92
12	3	1	CT	I	L	1	2	11.36	13.05	1.27	10.31
12	3	1	CT	I	L	1	3	17.19	22.40	2.16	10.39
12	3	1	CT	I	L	1	4	29.93	22.79	2.28	10.00
13	1	2	CT	I	L	1	1	0.48	53.70	2.73	19.66
13	1	2	CT	I	L	1	2	7.48	36.08	2.49	14.50
13	1	2	CT	I	L	1	3	12.64	39.06	3.21	12.16
13	1	2	CT	I	L	1	4	17.09	40.99	3.52	11.64
14	1	2	NT	I	L	1	1	0.00	66.86	3.60	18.58
14	1	2	NT	I	L	1	2	7.58	20.15	1.74	11.60
14	1	2	NT	I	L	1	3	12.67	47.30	3.80	12.43
14	1	2	NT	I	L	1	4	18.81	43.47	3.64	11.93
15	2	2	NT	I	H	1	1	0.57	44.08	4.74	9.30
15	2	2	NT	I	H	1	2	8.90	28.16	2.34	12.02
15	2	2	NT	I	H	1	3	14.63	48.83	3.91	12.48
15	2	2	NT	I	H	1	4	23.59	43.20	3.71	11.65
16	2	2	CT	I	L	1	1	0.35	53.70	2.73	19.66
16	2	2	CT	I	L	1	2	7.79	18.18	1.59	11.41
16	2	2	CT	I	L	1	3	14.29	29.62	2.55	11.63
16	2	2	CT	I	L	1	4	21.64	28.96	2.75	10.54
17	3	2	NT	I	H	1	1	0.18	44.08	4.74	9.30
17	3	2	NT	I	H	1	2	10.04	28.93	2.57	11.25
17	3	2	NT	I	H	1	3	19.72	41.28	3.74	11.02
17	3	2	NT	I	H	1	4	33.43	35.69	3.44	10.36
18	3	2	CT	I	L	1	1	0.48	53.70	2.73	19.66
18	3	2	CT	I	L	1	2	11.56	23.73	2.02	11.72
18	3	2	CT	I	L	1	3	18.30	35.56	3.16	11.27
18	3	2	CT	I	L	1	4	28.08	28.94	2.74	10.56
19	1	2	CT	I	H	1	1	0.95	91.39	6.49	14.08
19	1	2	CT	I	H	1	2	8.26	17.94	1.79	10.04
19	1	2	CT	I	H	1	3	11.32	41.36	3.58	11.56
19	1	2	CT	I	H	1	4	13.89	43.65	3.80	11.50
20	1	2	NT	I	H	1	1	0.46	44.08	4.74	9.30
20	1	2	NT	I	H	1	2	10.01	30.90	2.61	11.86
20	1	2	NT	I	H	1	3	14.02	49.16	4.11	11.97
20	1	2	NT	I	H	1	4	21.13	43.85	3.88	11.30
21	2	2	NT	I	L	1	1	0.35	66.86	3.60	18.58
21	2	2	NT	I	L	1	2	9.77	37.21	3.23	11.54
21	2	2	NT	I	L	1	3	18.20	45.78	3.92	11.69
21	2	2	NT	I	L	1	4	26.69	35.73	3.27	10.94
22	2	2	CT	I	H	1	1	0.00	91.39	6.49	14.08

22	2	2	CT	I	H	1	2	10.11	30.32	2.98	10.18
22	2	2	CT	I	H	1	3	19.28	38.33	3.58	10.71
22	2	2	CT	I	H	1	4	28.38	30.15	2.98	10.14
23	3	2	NT	I	L	1	1	0.20	66.86	3.60	18.58
23	3	2	NT	I	L	1	2	10.41	31.58	2.83	11.15
23	3	2	NT	I	L	1	3	22.14	43.58	3.89	11.19
23	3	2	NT	I	L	1	4	29.32	34.83	3.24	10.76
24	3	2	CT	I	H	1	1	0.74	91.39	6.49	14.08
24	3	2	CT	I	H	1	2	11.63	19.33	1.88	10.26
24	3	2	CT	I	H	1	3	18.84	30.19	2.84	10.62
24	3	2	CT	I	H	1	4	26.19	29.68	2.87	10.34
25	1	1	CT	NI	H	1	1	0.37	28.83	2.61	11.06
25	1	1	CT	NI	H	1	2	5.97	16.71	1.70	9.83
25	1	1	CT	NI	H	1	3	9.71	20.95	2.06	10.19
25	1	1	CT	NI	H	1	4	19.82	22.81	2.31	9.86
26	1	1	NT	NI	H	1	1	0.17	40.15	2.23	18.04
26	1	1	NT	NI	H	1	2	4.85	35.25	2.89	12.19
26	1	1	NT	NI	H	1	3	11.76	42.00	3.64	11.52
26	1	1	NT	NI	H	1	4	21.94	39.80	3.63	10.96
27	2	1	NT	NI	H	1	1	0.12	40.15	2.23	18.04
27	2	1	NT	NI	H	1	2	5.29	28.14	2.48	11.34
27	2	1	NT	NI	H	1	3	16.08	39.82	3.53	11.27
27	2	1	NT	NI	H	1	4	31.04	34.08	3.15	10.82
28	2	1	CT	NI	L	1	1	0.54	22.23	1.91	11.66
28	2	1	CT	NI	L	1	2	6.71	17.27	1.68	10.27
28	2	1	CT	NI	L	1	3	14.02	25.96	2.47	10.52
28	2	1	CT	NI	L	1	4	23.90	23.67	2.32	10.21
29	3	1	NT	NI	H	1	1	0.36	40.15	2.23	18.04
29	3	1	NT	NI	H	1	2	6.61	23.38	2.13	10.96
29	3	1	NT	NI	H	1	3	17.73	32.34	2.96	10.92
29	3	1	NT	NI	H	1	4	31.21	30.25	2.79	10.85
30	3	1	CT	NI	L	1	1	0.31	22.23	1.91	11.66
30	3	1	CT	NI	L	1	2	11.19	17.76	1.71	10.40
30	3	1	CT	NI	L	1	3	22.08	24.35	2.34	10.42
30	3	1	CT	NI	L	1	4	35.36	22.60	2.22	10.19
31	1	1	CT	NI	L	1	1	1.94	22.23	1.91	11.66
31	1	1	CT	NI	L	1	2	7.85	21.51	2.09	10.31
31	1	1	CT	NI	L	1	3	15.60	25.73	2.46	10.44
31	1	1	CT	NI	L	1	4	40.21	24.15	2.41	10.02
32	1	1	NT	NI	L	1	1	0.49	47.50	2.52	18.87
32	1	1	NT	NI	L	1	2	6.27	35.18	3.09	11.37
32	1	1	NT	NI	L	1	3	16.82	36.56	3.27	11.19
32	1	1	NT	NI	L	1	4	30.87	29.96	2.87	10.43

33	2	1	NT	NI	L	1	1	0.00	47.50	2.52	18.87
33	2	1	NT	NI	L	1	2	7.08	24.94	2.35	10.61
33	2	1	NT	NI	L	1	3	18.98	36.18	3.25	11.13
33	2	1	NT	NI	L	1	4	36.23	29.75	2.86	10.39
34	2	1	CT	NI	H	1	1	0.40	28.83	2.61	11.06
34	2	1	CT	NI	H	1	2	7.31	19.54	1.95	10.05
34	2	1	CT	NI	H	1	3	13.31	25.11	2.55	9.85
34	2	1	CT	NI	H	1	4	26.59	22.56	2.33	9.68
35	3	1	NT	NI	L	1	1	0.20	47.50	2.52	18.87
35	3	1	NT	NI	L	1	2	33.74	24.98	2.27	10.99
35	3	1	NT	NI	L	1	3	17.09	29.99	2.75	10.92
35	3	1	NT	NI	L	1	4	6.17	26.44	2.62	10.10
36	3	1	CT	NI	H	1	1	0.29	28.83	2.61	11.06
36	3	1	CT	NI	H	1	2	8.97	17.82	1.78	10.03
36	3	1	CT	NI	H	1	3	16.58	21.51	2.16	9.97
36	3	1	CT	NI	H	1	4	29.86	22.35	2.30	9.72
37	1	2	CT	NI	H	1	1	0.64	43.09	2.91	14.80
37	1	2	CT	NI	H	1	2	9.40	24.08	2.19	11.00
37	1	2	CT	NI	H	1	3	19.01	35.35	3.24	10.91
37	1	2	CT	NI	H	1	4	29.32	35.88	3.46	10.36
38	1	2	NT	NI	L	1	1	0.30	34.44	0.90	38.28
38	1	2	NT	NI	L	1	2	7.82	21.05	1.96	10.76
38	1	2	NT	NI	L	1	3	18.27	33.19	3.10	10.72
38	1	2	NT	NI	L	1	4	28.85	33.33	3.23	10.30
39	2	2	NT	NI	H	1	1	1.63	16.17	1.02	15.84
39	2	2	NT	NI	H	1	2	8.16	15.59	1.59	9.80
39	2	2	NT	NI	H	1	3	18.98	29.68	2.63	11.28
39	2	2	NT	NI	H	1	4	29.52	34.76	3.09	11.23
40	2	2	CT	NI	H	1	1	1.60	43.09	2.91	14.80
40	2	2	CT	NI	H	1	2	9.23	25.90	2.30	11.24
40	2	2	CT	NI	H	1	3	19.55	27.97	2.67	10.48
40	2	2	CT	NI	H	1	4	32.66	26.45	2.68	9.87
41	3	2	NT	NI	L	1	1	0.17	34.44	0.90	38.28
41	3	2	NT	NI	L	1	2	7.31	15.86	1.60	9.94
41	3	2	NT	NI	L	1	3	16.48	27.10	2.62	10.36
41	3	2	NT	NI	L	1	4	24.30	27.71	2.74	10.12
42	3	2	CT	NI	H	1	1	0.00	43.09	2.91	14.80
42	3	2	CT	NI	H	1	2	15.67	24.39	2.21	11.06
42	3	2	CT	NI	H	1	3	32.96	25.10	2.37	10.57
42	3	2	CT	NI	H	1	4	42.64	24.78	2.49	9.95
43	1	2	CT	NI	L	1	1	0.78	34.97	2.99	11.71
43	1	2	CT	NI	L	1	2	14.05	20.58	2.08	9.88
43	1	2	CT	NI	L	1	3	26.66	26.44	2.72	9.71

43	1	2	CT	NI	L	1	4	56.12	23.49	2.57	9.13
44	1	2	NT	NI	H	1	1	0.40	16.17	1.02	15.84
44	1	2	NT	NI	H	1	2	14.63	25.11	2.24	11.23
44	1	2	NT	NI	H	1	3	28.68	34.22	2.96	11.57
44	1	2	NT	NI	H	1	4	35.32	33.28	2.97	11.22
45	2	2	NT	NI	L	1	1	0.07	34.44	0.90	38.28
45	2	2	NT	NI	L	1	2	12.30	12.42	1.29	9.60
45	2	2	NT	NI	L	1	3	23.76	29.27	2.76	10.61
45	2	2	NT	NI	L	1	4	32.42	28.80	2.84	10.14
46	2	2	CT	NI	L	1	1	1.18	34.97	2.99	11.71
46	2	2	CT	NI	L	1	2	12.94	21.84	2.12	10.32
46	2	2	CT	NI	L	1	3	23.12	26.50	2.62	10.10
46	2	2	CT	NI	L	1	4	38.59	27.19	2.77	9.81
47	3	2	NT	NI	H	1	1	1.90	16.17	1.02	15.84
47	3	2	NT	NI	H	1	2	10.41	33.70	2.90	11.64
47	3	2	NT	NI	H	1	3	22.04	38.63	3.37	11.47
47	3	2	NT	NI	H	1	4	33.81	32.41	2.96	10.95
48	3	2	CT	NI	L	1	1	0.57	34.97	2.99	11.71
48	3	2	CT	NI	L	1	2	9.77	21.00	2.16	9.72
48	3	2	CT	NI	L	1	3	23.39	28.90	2.87	10.07
48	3	2	CT	NI	L	1	4	47.52	24.68	2.59	9.54
1	1	1	CT	I	H	2	1	0.39	27.84	1.65	16.90
1	1	1	CT	I	H	2	2	8.06	27.39	3.26	8.41
1	1	1	CT	I	H	2	3	10.38	36.38	3.08	11.82
1	1	1	CT	I	H	2	4	16.62	30.67	3.84	8.00
2	1	1	NT	I	L	2	1	0.40	38.83	3.13	12.42
2	1	1	NT	I	L	2	2	9.98	19.45	1.49	13.09
2	1	1	NT	I	L	2	3	14.22	26.41	2.35	11.26
2	1	1	NT	I	L	2	4	23.19	21.63	2.26	9.58
3	2	1	NT	I	H	2	1	0.23	9.26	0.61	15.11
3	2	1	NT	I	H	2	2	9.57	15.27	1.00	15.28
3	2	1	NT	I	H	2	3	10.28	20.57	1.65	12.46
3	2	1	NT	I	H	2	4	15.71	22.78	2.09	10.92
4	2	1	CT	I	L	2	1	0.44	29.20	1.22	24.01
4	2	1	CT	I	L	2	2	11.56	23.77	2.26	10.52
4	2	1	CT	I	L	2	3	16.08	25.08	2.17	11.58
4	2	1	CT	I	L	2	4	27.47	20.66	1.36	15.16
5	3	1	NT	I	L	2	1	0.58	38.83	3.13	12.42
5	3	1	NT	I	L	2	2	13.99	12.38	1.21	10.23
5	3	1	NT	I	L	2	3	17.12	23.63	2.07	11.43
5	3	1	NT	I	L	2	4	33.00	28.90	2.81	10.27
6	3	1	CT	I	H	2	1	0.24	27.84	1.65	16.90
6	3	1	CT	I	H	2	2	12.87	9.88	1.79	5.53

6	3	1	CT	I	H	2	3	15.77	16.11	3.02	5.34
6	3	1	CT	I	H	2	4	25.01	19.54	2.99	6.54
7	1	1	CT	I	L	2	1	0.30	29.20	1.22	24.01
7	1	1	CT	I	L	2	2	6.67	20.16	1.22	16.46
7	1	1	CT	I	L	2	3	8.19	28.14	2.05	13.76
7	1	1	CT	I	L	2	4	19.51	25.05	2.23	11.23
8	1	1	NT	I	H	2	1	0.74	9.26	0.61	15.11
8	1	1	NT	I	H	2	2	9.17	13.02	0.80	16.21
8	1	1	NT	I	H	2	3	8.29	20.03	1.35	14.85
8	1	1	NT	I	H	2	4	12.40	22.17	1.90	11.69
9	2	1	NT	I	L	2	1	0.34	38.83	3.13	12.42
9	2	1	NT	I	L	2	2	9.37	15.17	1.00	15.12
9	2	1	NT	I	L	2	3	16.72	22.64	2.08	10.90
9	2	1	NT	I	L	2	4	33.30	22.86	2.28	10.03
10	2	1	CT	I	H	2	1	0.36	27.84	1.65	16.90
10	2	1	CT	I	H	2	2	12.27	12.02	1.89	6.36
10	2	1	CT	I	H	2	3	14.73	21.97	2.70	8.12
10	2	1	CT	I	H	2	4	25.21	22.00	2.79	7.89
11	3	1	NT	I	H	2	1	0.29	9.26	0.61	15.11
11	3	1	NT	I	H	2	2	14.73	11.79	0.88	13.34
11	3	1	NT	I	H	2	3	13.72	12.96	1.17	11.09
11	3	1	NT	I	H	2	4	19.51	16.80	1.69	9.96
12	3	1	CT	I	L	2	1	0.30	29.20	1.22	24.01
12	3	1	CT	I	L	2	2	11.16	8.16	0.79	10.33
12	3	1	CT	I	L	2	3	18.13	19.59	1.98	9.90
12	3	1	CT	I	L	2	4	30.40	17.43	1.57	11.12
13	1	2	CT	I	L	2	1	0.22	21.98	1.79	12.27
13	1	2	CT	I	L	2	2	7.79	14.25	1.06	13.40
13	1	2	CT	I	L	2	3	10.28	28.04	2.26	12.40
13	1	2	CT	I	L	2	4	13.31	34.73	2.98	11.66
14	1	2	NT	I	L	2	1	0.61	13.69	0.57	23.83
14	1	2	NT	I	L	2	2	8.06	12.57	0.86	14.60
14	1	2	NT	I	L	2	3	10.52	19.32	1.53	12.61
14	1	2	NT	I	L	2	4	15.74	23.40	2.07	11.32
15	2	2	NT	I	H	2	1	0.00	33.97	1.26	26.94
15	2	2	NT	I	H	2	2	8.02	25.92	2.14	12.11
15	2	2	NT	I	H	2	3	12.44	24.62	1.57	15.69
15	2	2	NT	I	H	2	4	16.72	24.76	2.38	10.39
16	2	2	CT	I	L	2	1	0.61	21.98	1.79	12.27
16	2	2	CT	I	L	2	2	7.65	19.05	1.23	15.44
16	2	2	CT	I	L	2	3	14.93	24.85	2.15	11.55
16	2	2	CT	I	L	2	4	25.08	25.38	2.35	10.81
17	3	2	NT	I	H	2	1	0.30	33.97	1.26	26.94

17	3	2	NT	I	H	2	2	9.20	9.54	1.24	7.70
17	3	2	NT	I	H	2	3	14.46	16.79	1.46	11.52
17	3	2	NT	I	H	2	4	19.75	21.65	2.32	9.34
18	3	2	CT	I	L	2	1	0.70	21.98	1.79	12.27
18	3	2	CT	I	L	2	2	9.34	15.00	1.17	12.78
18	3	2	CT	I	L	2	3	16.38	21.17	1.89	11.19
18	3	2	CT	I	L	2	4	27.77	23.82	2.33	10.23
19	1	2	CT	I	H	2	1	0.55	17.68	1.16	15.20
19	1	2	CT	I	H	2	2	8.43	19.27	1.47	13.14
19	1	2	CT	I	H	2	3	10.72	32.66	2.53	12.89
19	1	2	CT	I	H	2	4	13.41	35.19	2.92	12.04
20	1	2	NT	I	H	2	1	0.24	33.97	1.26	26.94
20	1	2	NT	I	H	2	2	8.26	11.95	1.21	9.87
20	1	2	NT	I	H	2	3	10.11	20.45	1.61	12.69
20	1	2	NT	I	H	2	4	14.43	26.52	2.90	9.15
21	2	2	NT	I	L	2	1	0.17	13.69	0.57	23.83
21	2	2	NT	I	L	2	2	8.09	13.04	0.85	15.32
21	2	2	NT	I	L	2	3	12.94	20.13	1.66	12.15
21	2	2	NT	I	L	2	4	19.89	22.58	2.10	10.74
22	2	2	CT	I	H	2	1	0.60	17.68	1.16	15.20
22	2	2	CT	I	H	2	2	9.27	21.09	1.83	11.53
22	2	2	CT	I	H	2	3	17.86	29.99	2.59	11.60
22	2	2	CT	I	H	2	4	26.12	26.19	2.65	9.90
23	3	2	NT	I	L	2	1	0.00	13.69	0.57	23.83
23	3	2	NT	I	L	2	2	9.30	15.56	1.14	13.69
23	3	2	NT	I	L	2	3	17.32	21.69	1.88	11.54
23	3	2	NT	I	L	2	4	23.69	21.98	2.08	10.59
24	3	2	CT	I	H	2	1	0.44	17.68	1.16	15.20
24	3	2	CT	I	H	2	2	9.00	11.88	1.01	11.82
24	3	2	CT	I	H	2	3	14.96	18.48	1.81	10.22
24	3	2	CT	I	H	2	4	25.95	23.34	2.15	10.83
25	1	1	CT	NI	H	2	1	0.30	37.85	2.28	16.63
25	1	1	CT	NI	H	2	2	4.68	17.81	1.52	11.74
25	1	1	CT	NI	H	2	3	10.82	24.86	2.16	11.52
25	1	1	CT	NI	H	2	4	19.28	25.02	2.31	10.81
26	1	1	NT	NI	H	2	1	0.20	79.15	3.48	22.74
26	1	1	NT	NI	H	2	2	4.38	11.98	0.87	13.79
26	1	1	NT	NI	H	2	3	8.22	18.60	1.64	11.30
26	1	1	NT	NI	H	2	4	14.93	21.12	1.97	10.73
27	2	1	NT	NI	H	2	1	0.00	79.15	3.48	22.74
27	2	1	NT	NI	H	2	2	4.75	14.04	1.10	12.82
27	2	1	NT	NI	H	2	3	8.39	18.75	1.55	12.07
27	2	1	NT	NI	H	2	4	15.50	21.13	1.96	10.79

28	2	1	CT	NI	L	2	1	0.00	132.89	0.98	13.63
28	2	1	CT	NI	L	2	2	5.22	17.57	1.43	12.32
28	2	1	CT	NI	L	2	3	13.55	27.41	2.36	11.63
28	2	1	CT	NI	L	2	4	18.00	28.02	2.52	11.13
29	3	1	NT	NI	H	2	1	0.10	79.15	3.48	22.74
29	3	1	NT	NI	H	2	2	5.83	13.16	1.53	8.61
29	3	1	NT	NI	H	2	3	13.41	18.41	1.63	11.32
29	3	1	NT	NI	H	2	4	21.67	21.09	1.95	10.83
30	3	1	CT	NI	L	2	1	0.00	132.89	0.98	136.28
30	3	1	CT	NI	L	2	2	6.40	16.70	1.31	12.72
30	3	1	CT	NI	L	2	3	13.25	25.58	2.14	11.93
30	3	1	CT	NI	L	2	4	19.72	24.37	2.15	11.31
31	1	1	CT	NI	L	2	1	0.25	132.89	0.98	136.28
31	1	1	CT	NI	L	2	2	4.99	7.95	0.68	11.66
31	1	1	CT	NI	L	2	3	11.39	16.45	1.39	11.86
31	1	1	CT	NI	L	2	4	22.14	18.72	1.68	11.13
32	1	1	NT	NI	L	2	1	0.32	28.17	1.10	25.72
32	1	1	NT	NI	L	2	2	4.79	15.39	2.48	6.22
32	1	1	NT	NI	L	2	3	8.56	16.63	1.43	11.66
32	1	1	NT	NI	L	2	4	14.73	20.20	1.88	10.77
33	2	1	NT	NI	L	2	1	0.00	28.17	1.10	25.72
33	2	1	NT	NI	L	2	2	5.33	10.38	0.90	11.59
33	2	1	NT	NI	L	2	3	11.16	16.64	1.51	11.06
33	2	1	NT	NI	L	2	4	16.55	20.54	1.91	10.75
34	2	1	CT	NI	H	2	1	0.55	37.85	2.28	16.63
34	2	1	CT	NI	H	2	2	4.58	14.72	1.27	11.56
34	2	1	CT	NI	H	2	3	11.09	21.83	1.96	11.15
34	2	1	CT	NI	H	2	4	18.10	24.75	2.29	10.80
35	3	1	NT	NI	L	2	1	0.00	28.17	1.10	25.72
35	3	1	NT	NI	L	2	2	6.40	12.43	0.87	14.27
35	3	1	NT	NI	L	2	3	12.23	14.97	1.24	12.03
35	3	1	NT	NI	L	2	4	16.95	17.93	1.66	10.82
36	3	1	CT	NI	H	2	1	0.39	37.85	2.28	16.63
36	3	1	CT	NI	H	2	2	7.82	12.64	1.10	11.52
36	3	1	CT	NI	H	2	3	15.67	17.68	1.68	10.53
36	3	1	CT	NI	H	2	4	24.40	19.77	1.94	10.20
37	1	2	CT	NI	H	2	1	0.00	42.13	1.85	22.82
37	1	2	CT	NI	H	2	2	11.53	13.96	1.32	10.59
37	1	2	CT	NI	H	2	3	22.78	21.93	2.07	10.58
37	1	2	CT	NI	H	2	4	36.87	25.50	2.45	10.41
38	1	2	NT	NI	L	2	1	0.52	14.09	0.92	15.38
38	1	2	NT	NI	L	2	2	10.52	7.69	0.77	9.94
38	1	2	NT	NI	L	2	3	15.44	14.48	1.37	10.57

38	1	2	NT	NI	L	2	4	24.06	21.98	2.05	10.70
39	2	2	NT	NI	H	2	1	0.30	13.95	1.36	10.28
39	2	2	NT	NI	H	2	2	8.09	9.79	1.28	7.64
39	2	2	NT	NI	H	2	3	15.54	15.96	1.54	10.37
39	2	2	NT	NI	H	2	4	21.67	21.16	2.11	10.03
40	2	2	CT	NI	H	2	1	0.76	42.13	1.85	22.82
40	2	2	CT	NI	H	2	2	11.09	26.01	2.24	11.59
40	2	2	CT	NI	H	2	3	22.99	31.66	2.82	11.21
40	2	2	CT	NI	H	2	4	30.84	30.04	2.74	10.95
41	3	2	NT	NI	L	2	1	0.94	14.09	0.92	15.38
41	3	2	NT	NI	L	2	2	11.73	6.67	0.72	9.33
41	3	2	NT	NI	L	2	3	17.43	11.09	1.11	9.97
41	3	2	NT	NI	L	2	4	21.91	17.28	1.65	10.49
42	3	2	CT	NI	H	2	1	0.23	42.13	1.85	22.82
42	3	2	CT	NI	H	2	2	7.58	7.89	0.71	11.16
42	3	2	CT	NI	H	2	3	18.50	19.10	1.84	10.38
42	3	2	CT	NI	H	2	4	26.93	22.67	2.26	10.05
43	1	2	CT	NI	L	2	1	0.33	36.82	1.77	20.80
43	1	2	CT	NI	L	2	2	15.03	8.55	0.96	8.87
43	1	2	CT	NI	L	2	3	22.95	17.85	1.77	10.07
43	1	2	CT	NI	L	2	4	31.04	23.16	2.30	10.09
44	1	2	NT	NI	H	2	1	1.08	13.95	1.36	10.28
44	1	2	NT	NI	H	2	2	12.84	11.81	1.06	11.12
44	1	2	NT	NI	H	2	3	22.21	27.28	2.37	11.53
44	1	2	NT	NI	H	2	4	34.82	29.77	2.69	11.06
45	2	2	NT	NI	L	2	1	0.68	14.09	0.92	15.38
45	2	2	NT	NI	L	2	2	13.48	6.33	0.71	8.96
45	2	2	NT	NI	L	2	3	21.94	13.10	1.30	10.07
45	2	2	NT	NI	L	2	4	27.74	18.79	1.87	10.04
46	2	2	CT	NI	L	2	1	0.00	36.82	1.77	20.80
46	2	2	CT	NI	L	2	2	9.88	14.06	1.07	13.17
46	2	2	CT	NI	L	2	3	15.20	21.78	1.95	11.19
46	2	2	CT	NI	L	2	4	23.12	22.94	2.11	10.88
47	3	2	NT	NI	H	2	1	0.57	13.95	1.36	10.28
47	3	2	NT	NI	H	2	2	14.05	9.13	0.95	9.65
47	3	2	NT	NI	H	2	3	23.05	17.00	1.72	9.85
47	3	2	NT	NI	H	2	4	27.30	20.88	2.14	9.78
48	3	2	CT	NI	L	2	1	0.08	36.82	1.77	20.80
48	3	2	CT	NI	L	2	2	8.76	12.38	1.27	9.72
48	3	2	CT	NI	L	2	3	19.89	21.19	1.97	10.76
48	3	2	CT	NI	L	2	4	32.19	22.66	2.28	9.93

Table 1. Analysis of variance summary of the effects of irrigation, tillage, fertility, soil depth and their interactions on total water stable aggregate (TWSA; > 0.25-mm) concentration, TWSA carbon and nitrogen concentrations (C Conc. and N Conc.), TWSA C:N ratios, bulk-soil C and N concentrations, and bulk-soil C:N ratio after 9 years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text ($P < 0.05$).

		TWSA C and N			**Bulk-soil C and N**		
Treatment Effect	**TWSA**	**C Conc.**	**N Conc.**	**C:N Ratio**	**C Conc.**	**N Conc.**	**C:N Ratio**
	P						
Irrigation	0.727	0.180	**0.041**	0.654	0.704	0.797	0.094
Tillage	0.224	0.095	0.189	0.075	0.340	0.249	0.172
Irrigation*Tillage	0.074	0.719	0.861	0.568	0.208	0.242	0.599
Fertility	0.220	0.219	**0.032**	0.159	0.478	0.353	0.517
Irrigation *Fertility	0.343	0.072	0.665	**0.003**	**0.020**	**0.016**	0.888
Tillage *Fertility	0.822	0.389	0.396	0.128	0.416	0.347	0.896
Irrigation*Tillage* Fertility	**0.037**	0.197	0.090	0.151	0.110	0.185	0.171
Depth	0.058	**0.020**	**<0.001**	**<0.001**	0.088	0.115	**<0.001**
Irrigation*Depth	0.330	**0.028**	0.158	0.529	0.672	0.708	0.111
Tillage*Depth	0.504	**0.009**	**0.004**	0.121	**0.021**	**0.015**	**0.046**
Fertility*Depth	0.412	0.904	0.524	**0.021**	0.426	0.492	0.140
Irrigation*Tillage*Depth	0.066	0.791	0.300	0.053	0.583	0.556	0.701
Irrigation*Fertility*Depth	**0.028**	0.930	0.994	0.797	0.924	0.814	0.538
Tillage*Fertility* Depth	0.229	0.230	0.203	0.236	0.579	0.509	0.984
Irrigation*Tillage*Fertility*Depth	0.246	0.549	0.151	0.182	0.244	0.277	0.885

Table 2. Analysis of variance summary of the effects of irrigation, tillage, fertility, soil depth, and aggregate-size class, and their interactions on water-stable aggregate (WSA; > 0.25-mm) concentration, and WSA carbon (C) and nitrogen (N) concentrations and C:N ratios, after 9 years of consistent management at the University of Arkansas' Lon Mann Cotton Research Station near Marianna, AR on a silt-loam soil. Interactions and main effects that are considered significant are indicated by bolded text ($P < 0.05$).

		WSA C and N		
Treatment Effect	**WSA**	**C Conc.**	**N Conc.**	**C:N Ratio**
	———	——— *P* ———	———	
Irrigation	0.727	0.172	**0.027**	0.519
Tillage	0.224	0.115	0.324	**0.032**
Irrigation*Tillage	0.074	0.738	0.998	0.312
Fertility	0.220	0.320	0.077	0.096
Irrigation *Fertility	0.343	0.105	0.786	**0.004**
Tillage *Fertility	0.822	0.558	0.494	0.123
Irrigation*Tillage* Fertility	**0.037**	0.247	0.080	0.082
Depth	0.082	**0.007**	0.834	0.768
Irrigation*Depth	0.330	0.120	0.342	0.990
Tillage*Depth	0.504	**0.010**	**0.007**	0.188
Fertility*Depth	0.434	0.926	0.426	0.066
Irrigation*Tillage*Depth	0.093	0.974	0.388	0.130
Irrigation*Fertility*Depth	0.062	0.780	0.685	0.352
Tillage*Fertility* Depth	0.267	0.192	0.232	0.377
Depth*Irrigation*Tillage*Fertility	0.234	0.806	0.475	0.354
Size class	**0.004**	0.806	0.257	**<0.001**
Irrigation*Size class	0.659	0.156	0.244	0.084
Tillage*Size class	0.283	0.249	0.511	**0.040**
Fertility*Size class	0.297	0.298	0.251	0.098
Depth*Size class	**0.030**	**<0.001**	0.947	0.769
Irrigation*Tillage*Size class	**0.008**	0.868	0.850	**0.028**
Irrigation*Fertility*Size class	0.111	0.350	0.368	0.065
Irrigation*Depth*Size class	0.359	0.078	0.204	0.421
Tillage*Fertility*Size class	0.747	0.850	0.948	0.377
Tillage*Depth*Size class	0.529	**<0.001**	**0.002**	0.359
Fertility*Depth*Size class	0.936	0.384	0.663	0.226
Irrigation*Tillage*Fertility*Size class	**<0.001**	0.469	0.191	0.590
Irrigation*Tillage*Depth*Size class	**0.025**	0.897	0.405	0.076
Irrigation*Fertility*Depth*Size class	0.053	0.145	**0.048**	0.388
Tillage*Fertility*Depth*Size class	0.111	0.901	0.913	0.937
Irrigation*Tillage*Fertility*Depth*Size class	0.058	0.175	0.054	0.958

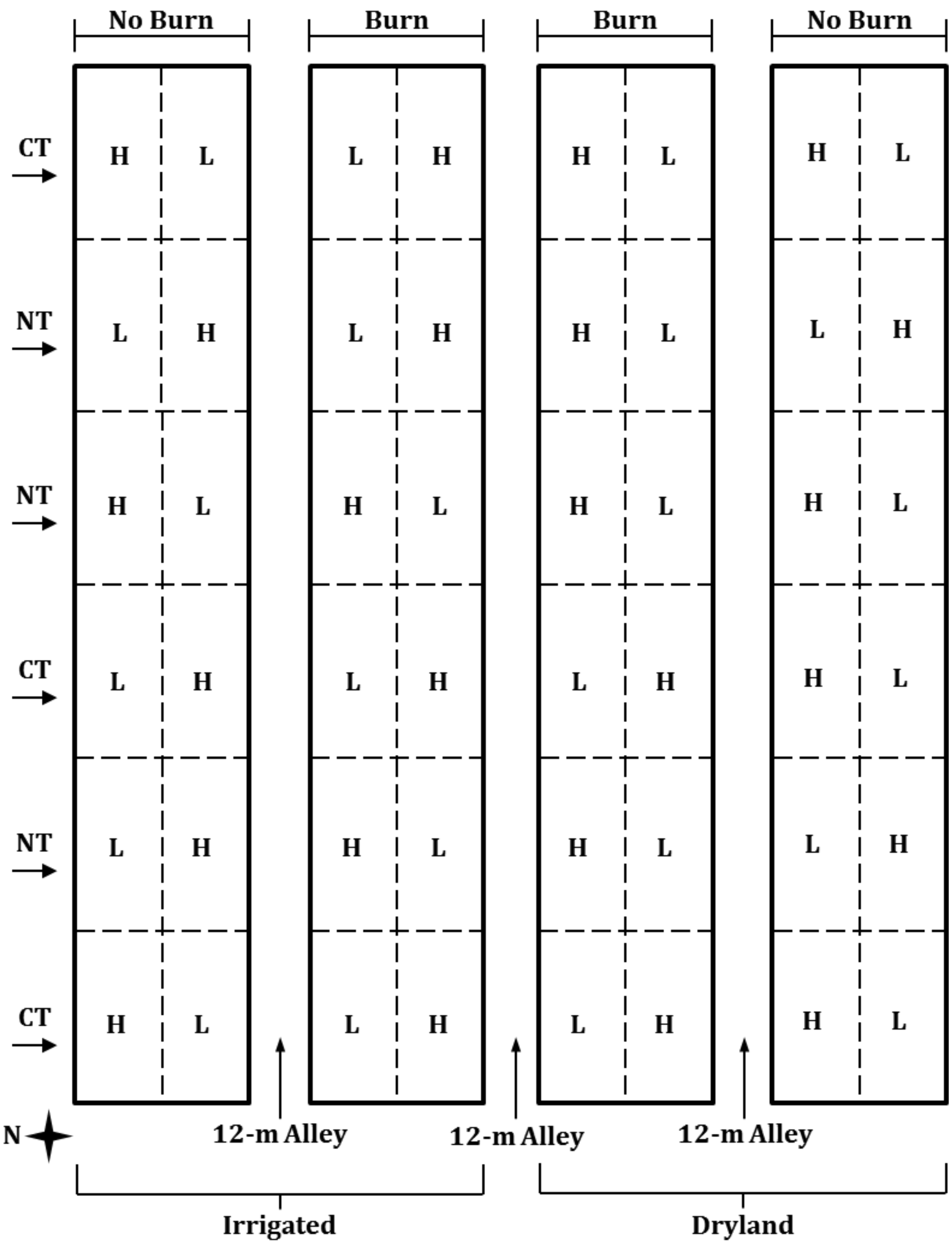

Fig. 1. Schematic diagram of the experimental layout at the Lon Mann Cotton Branch Experiment Station near Marianna in eastern Arkansas. High fertility (H), low fertility (L), conventional tillage (CT), and no-tillage (NT) residue treatments are shown.

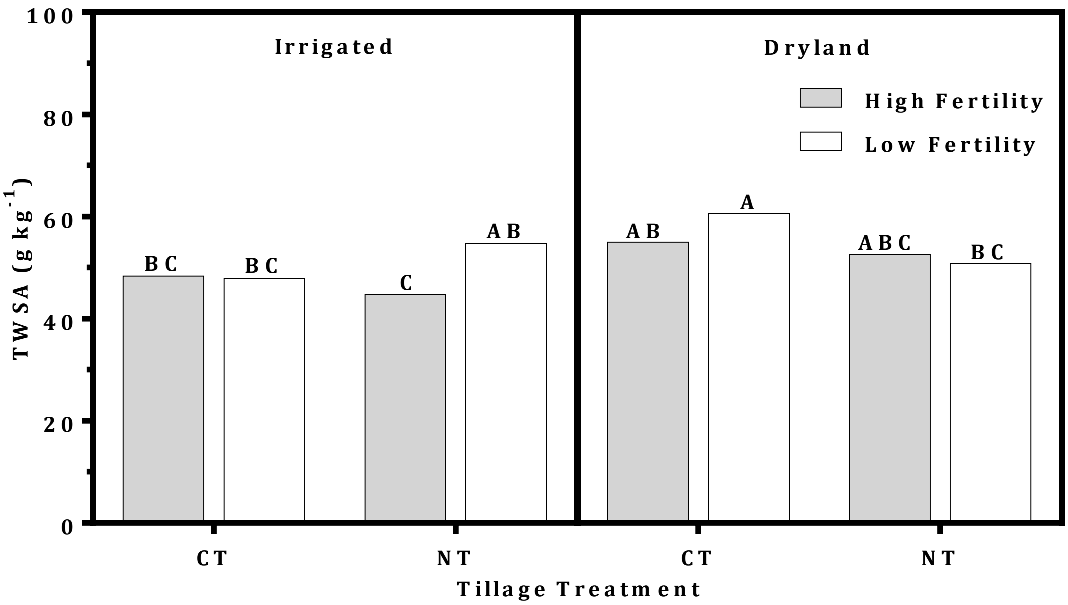

Fig. 2. Irrigation (irrigated and dryland), tillage [conventional (CT) and no-tillage (NT)], and fertility (high and low fertility) treatment effects on total water-stable aggregate (TWSA; > 0.25-mm) concentration. Different letters indicate significant differences between fertility treatments [least significant difference (LSD) = 8.2] or between tillage treatments (LSD = 9.5) within the same irrigation treatment. Different letters also indicate significant differences between different irrigation and different tillage treatments within the same fertility treatment (LSD = 8.5). There were no significant differences between irrigation treatments within the same tillage and fertility treatments (LSD = 229).

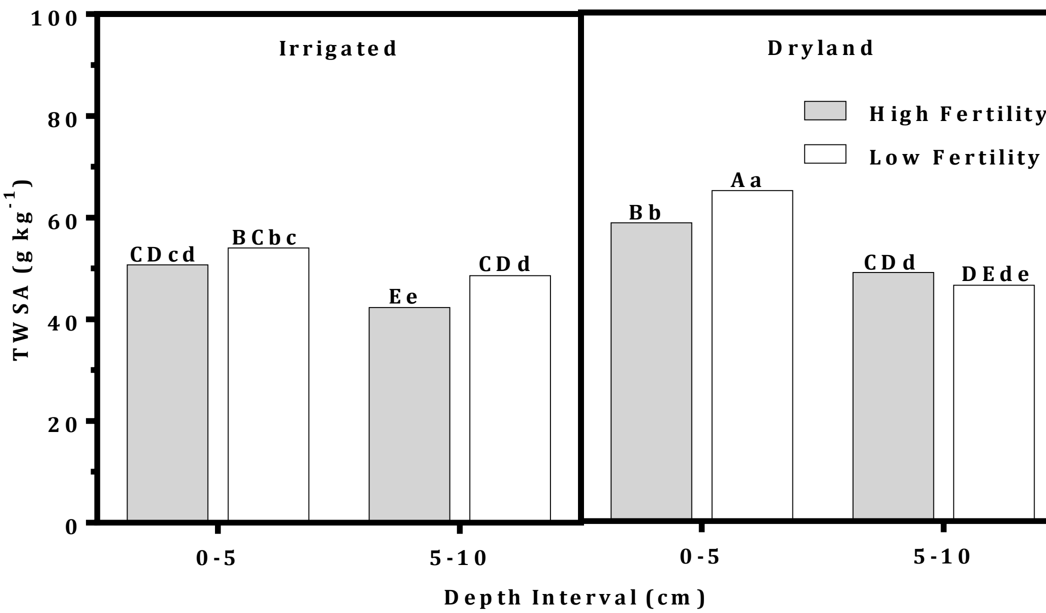

Fig. 3. Irrigation (irrigated and dryland), fertility (high and low fertility), and soil depth (0- to 5- and 5- to 10 cm) treatment effects on total water-stable aggregate (TWSA; > 0.25-mm) concentration. Different capital letters indicate significant differences between fertility treatments within the same irrigation and depth treatments [least significant difference (LSD) = 6.1]. Different lowercase letters indicate significant differences between depth treatments within the same irrigation and fertility treatments (LSD = 5.1). There were no significant differences between irrigation treatments within the same fertility and depth treatments or between different irrigation and different tillage treatments within the same depth treatment (LSD = 161).

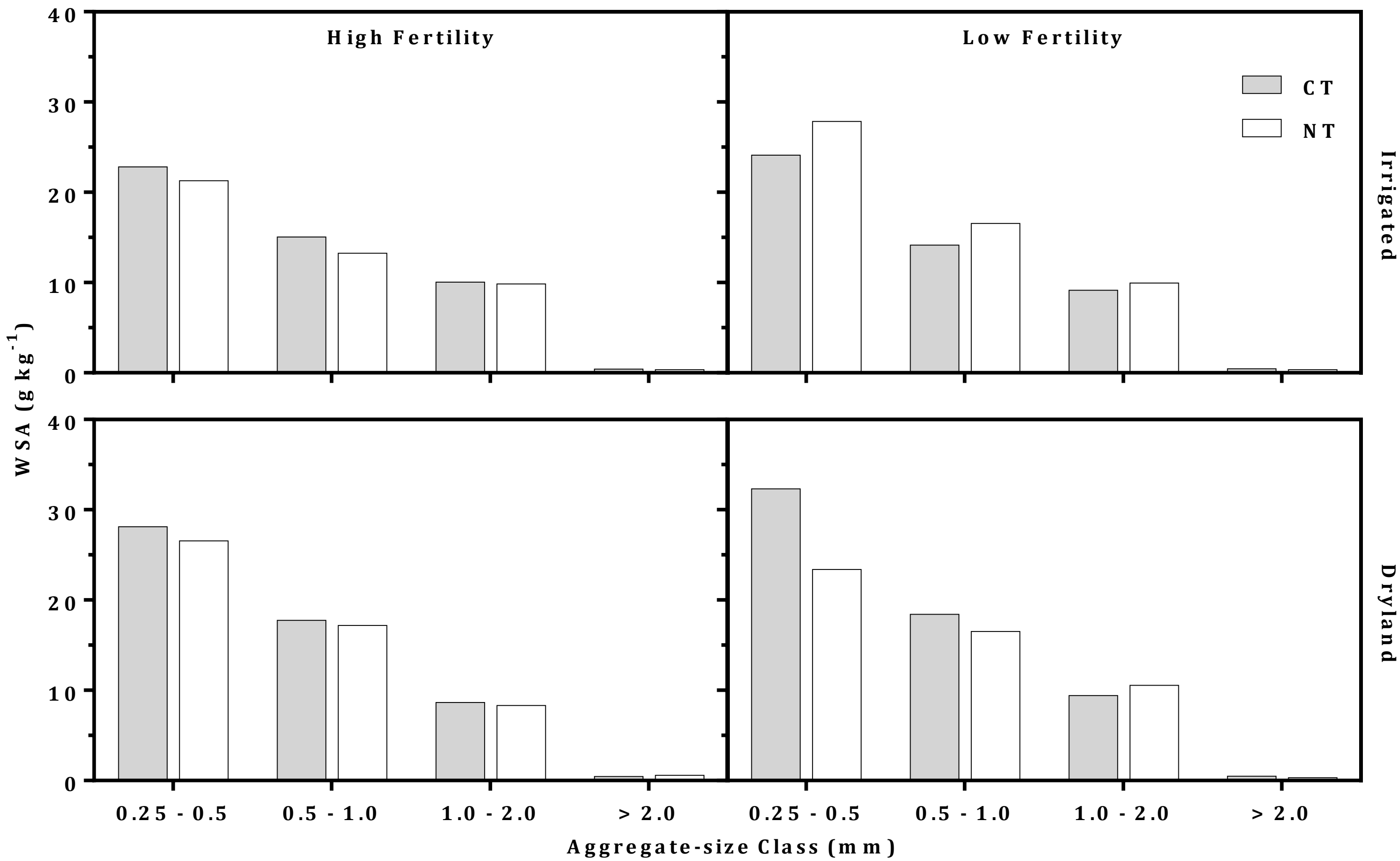

Fig. 4. Irrigation (irrigated and dryland), tillage [conventional (CT) and no-tillage (NT)], fertility (high and low fertility), and aggregate-size class effects on water-stable aggregate (WSA) concentration. Least significant differences (LSD) ranged from 1.9 to 81 g kg^{-1} depending on the treatment combinations being compared.

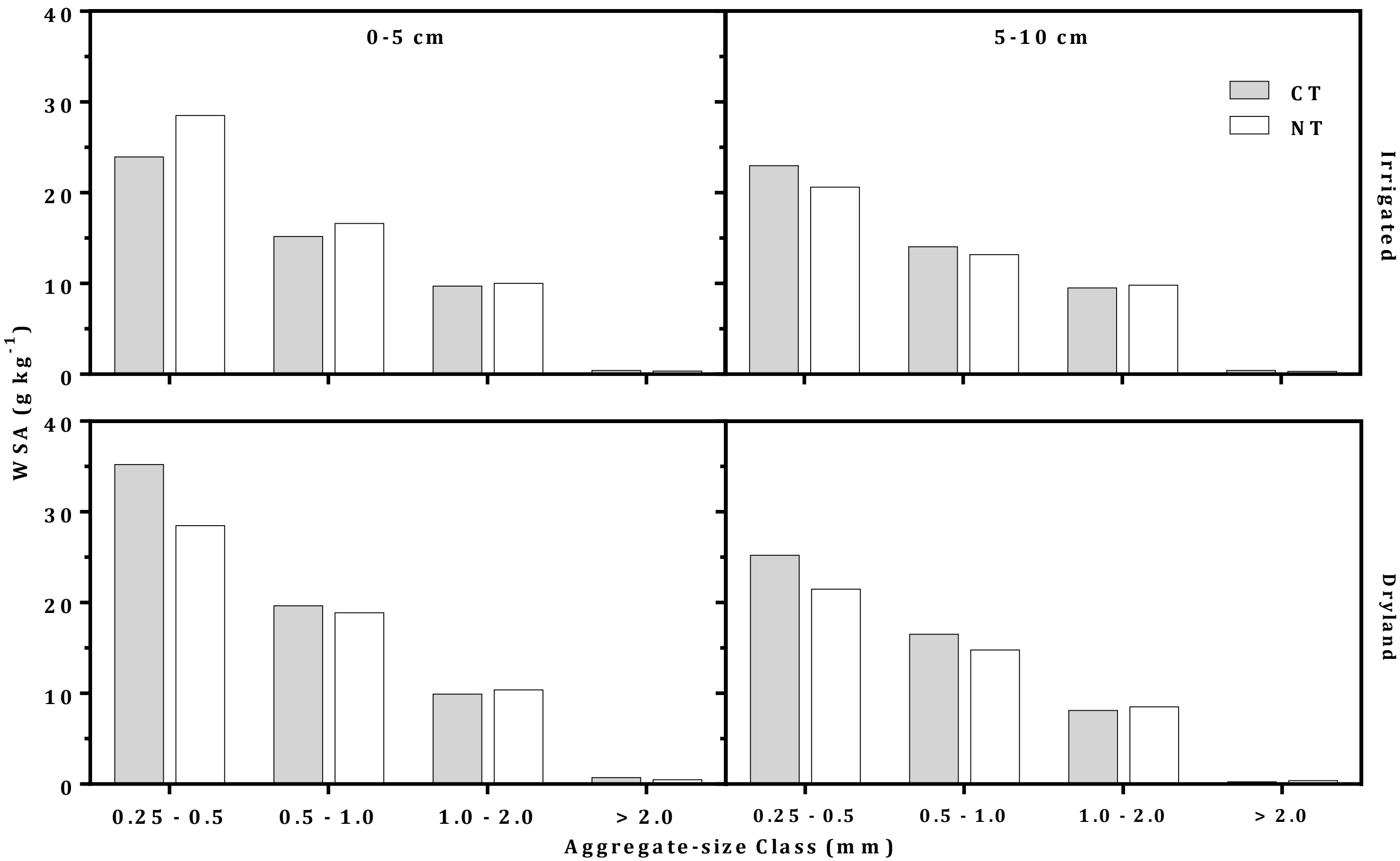

Fig. 5. Irrigation (irrigated and dryland), tillage (conventional and no-tillage), soil depth (0- to 5- and 5- to 10 cm), and aggregate-size class effects on water-stable aggregate (WSA) concentration. Least significant differences (LSD) ranged from 2.5 to 81 g kg^{-1} depending on the treatment combinations being compared.

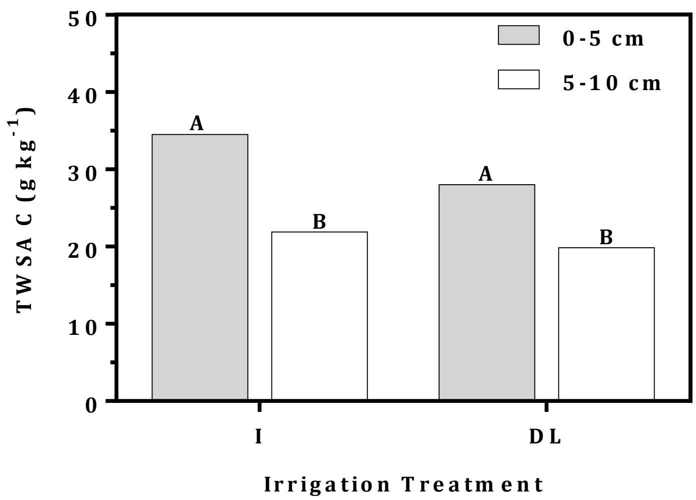

Fig. 6. Irrigation [irrigated (I) and dryland (DL)] and soil-depth (0- to 5-cm and 5- to 10 cm) effects on total water-stable aggregate (TWSA) carbon (C) concentration. Different letters indicate significant differences between depth treatments within the same irrigation treatment [least significant difference (LSD) = 1.8]. There were no significant differences between irrigation treatments within the same depth treatment or between different depth and different irrigation treatments (LSD = 15.8).

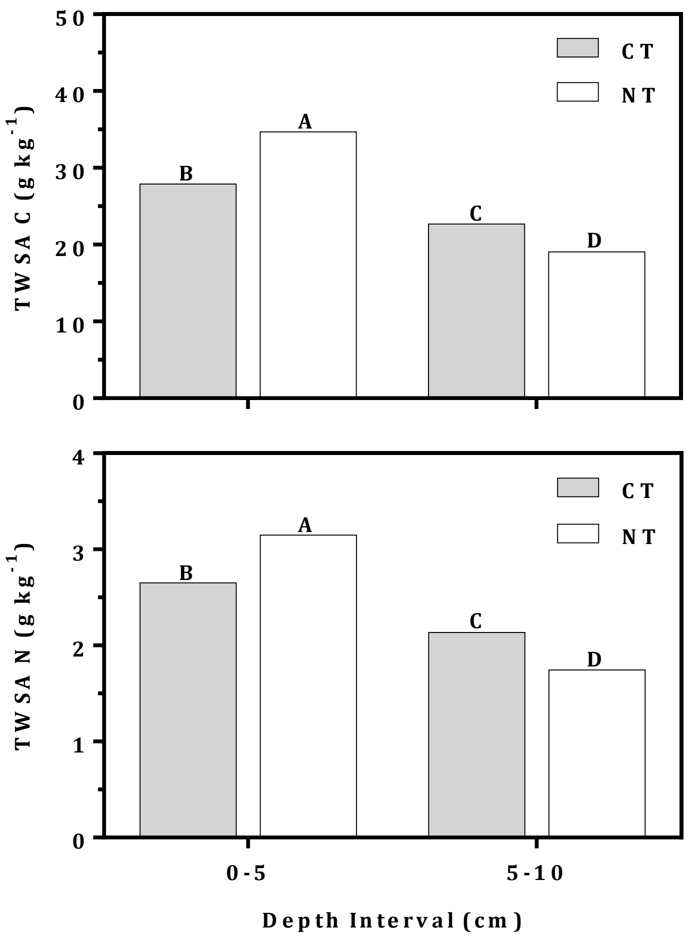

Fig. 7. Tillage [conventional (CT) and no-tillage (NT)] and soil depth (0- to 5- and 5- to 10 cm) effects on total water-stable aggregate (TWSA) nitrogen (N) and carbon (C) concentrations. For TWSA N, different letters indicate significant differences between tillage treatments within the same depth [least significant difference (LSD) = 3.0] and between depth treatments within the same tillage (LSD = 3.1). For TWSA C, different letters indicate significant differences between tillage treatments within the same depth (LSD = 0.17) and between depth treatments within the same tillage (LSD = 0.02).

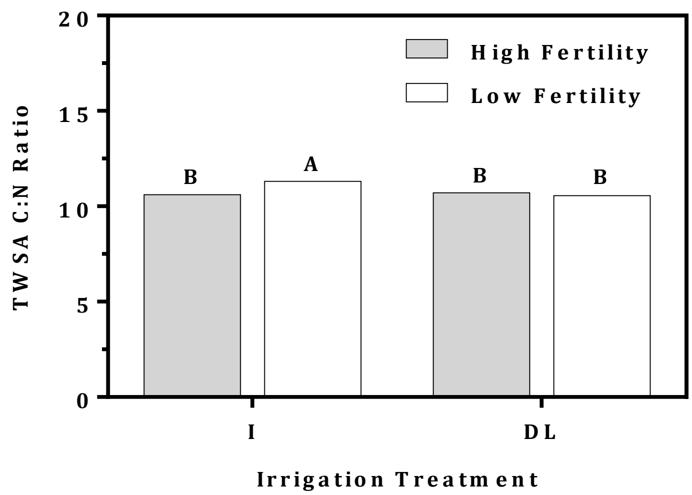

Fig. 8. Irrigation [irrigated (I) and dryland (DL)] and fertility (high and low fertility) effects on total water-stable aggregate (TWSA) carbon (C) to nitrogen (N) ratio. Different letters indicate significant differences between fertility treatments within the same irrigation treatment [least significant difference (LSD) = 0.29]. There were no significant differences between irrigation treatments within the same fertility treatment or between different fertility and different irrigation treatments (LSD = 6.77).

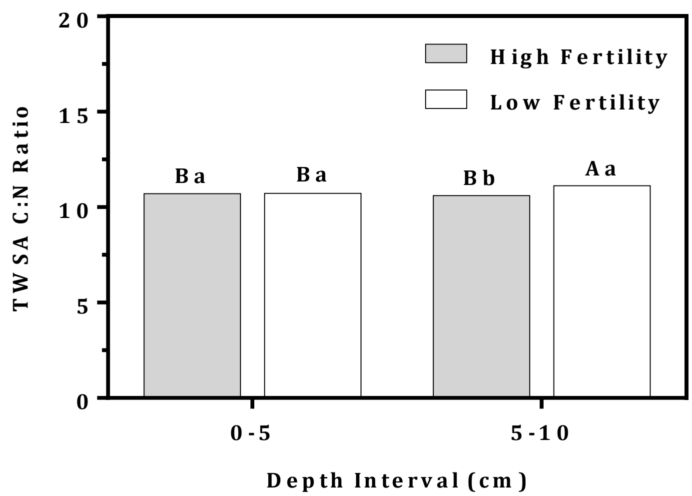

Fig. 9. Soil depth (0- to 5- and 5- to 10 cm) and fertility (high and low fertility) effects on total water-stable aggregate (TWSA) carbon (C) to nitrogen (N) ratio. Different capital letters indicate significant differences between fertility treatments within the same soil depth [least significant difference (LSD) = 0.29]. Different lowercase letters indicate significant differences between depths within the same fertility treatment (LSD = 0.48).

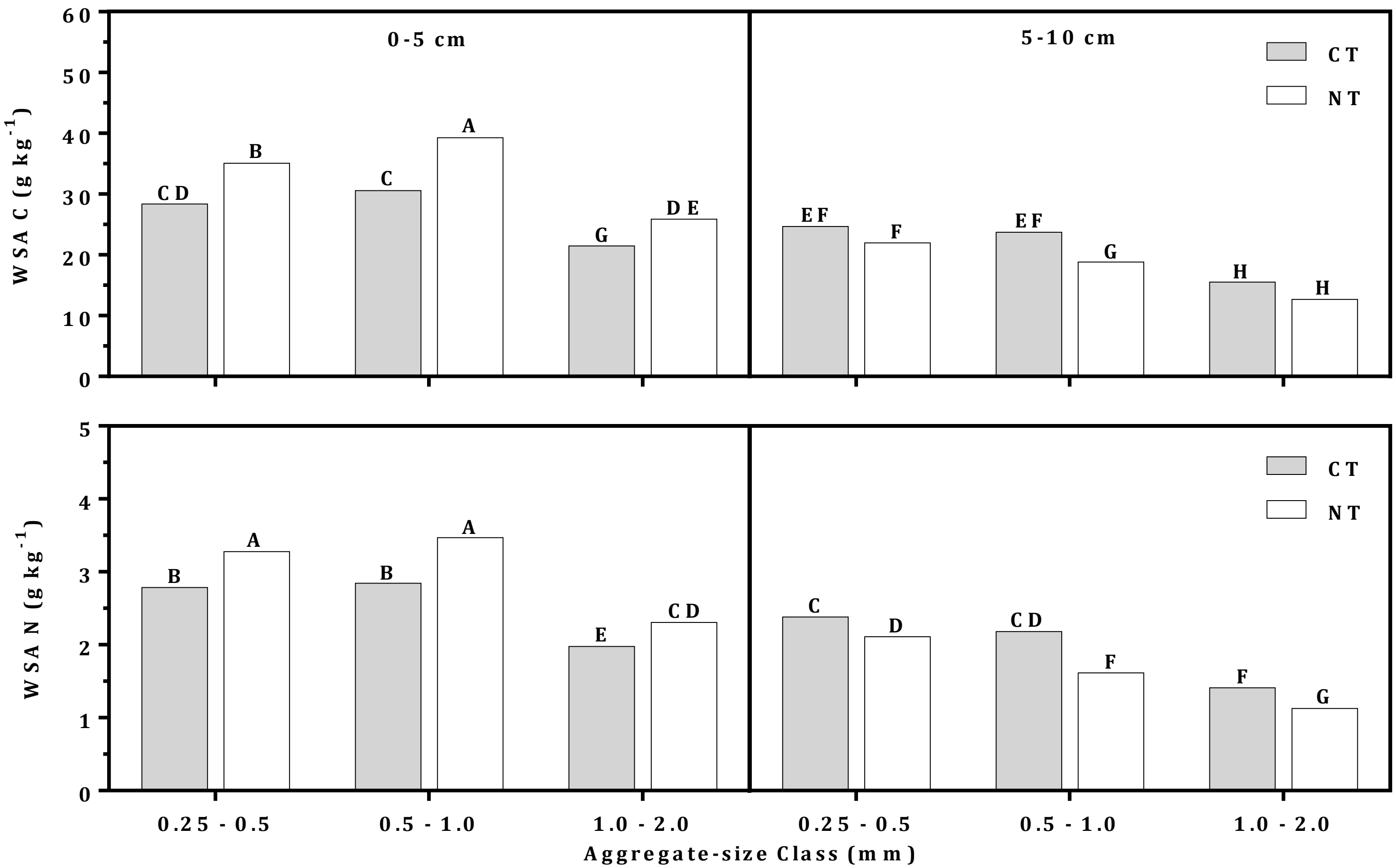

Fig. 10. Tillage [conventional (CT) and no-tillage (NT)], soil depth (0- to 5- and 5- to 10 cm), and aggregate-size class effects on water-stable aggregate (WSA) carbon (C) and nitrogen (N) concentrations in various size classes (> 0.25-mm diameter). The least significant difference (LSD) values ranged from 0.09 to 3.32 depending on the treatment combinations being compared. Different letters indicate significant differences separated by the most conservative LSD for carbon (3.32) and nitrogen (0.24) concentrations.

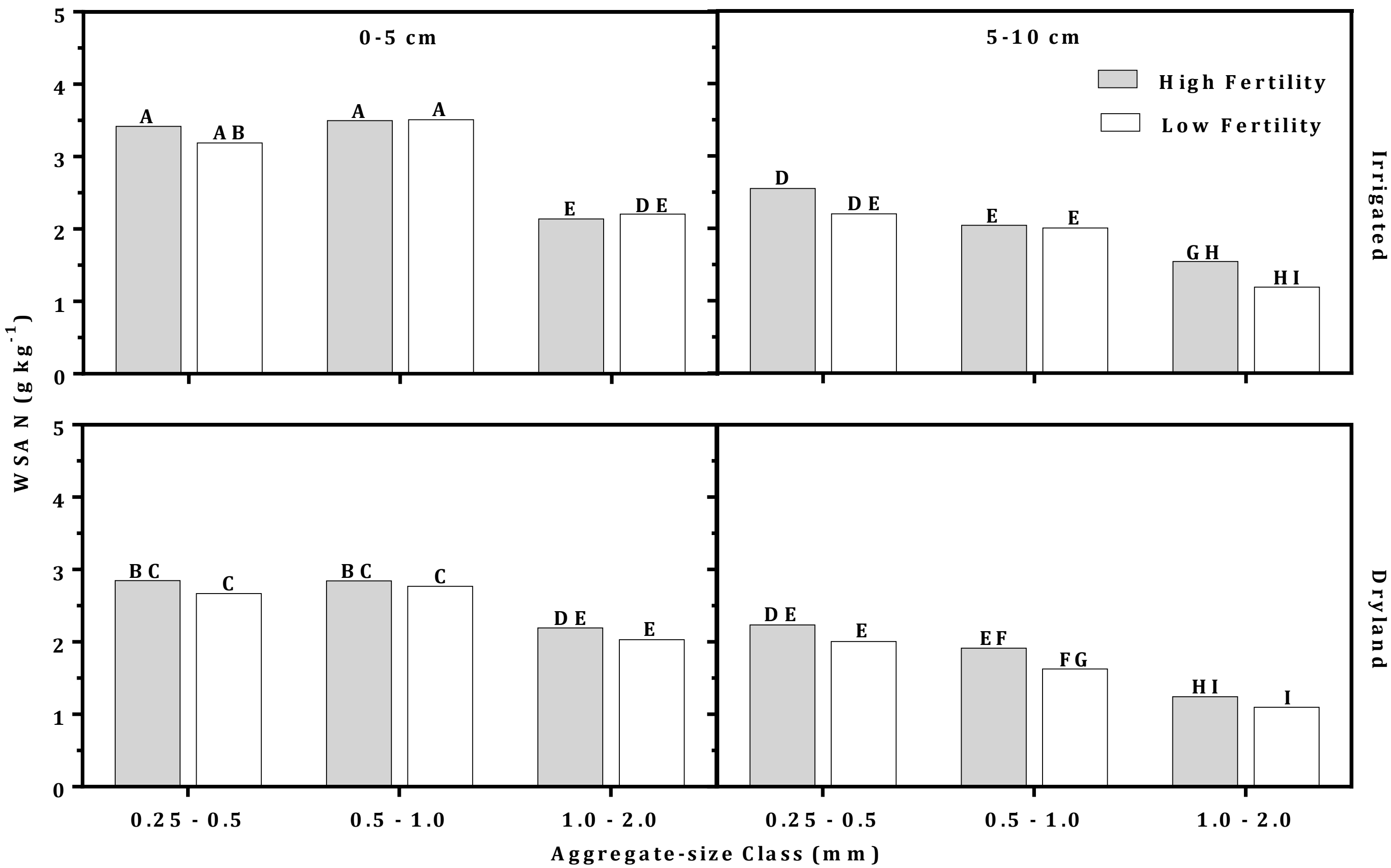

Fig. 11. Irrigation (irrigated and dryland), fertility (high and low fertility), soil depth (0- to 5- and 5- to 10 cm), and aggregate-size class effects on water-stable aggregate (WSA) nitrogen (N) concentration in various size classes (> 0.25-mm diameter). The least significant difference (LSD) values ranged from 0.16 to 0.37 depending on the treatment combinations being compared. Different letters indicate significant differences separated by the most conservative LSD (0.37).

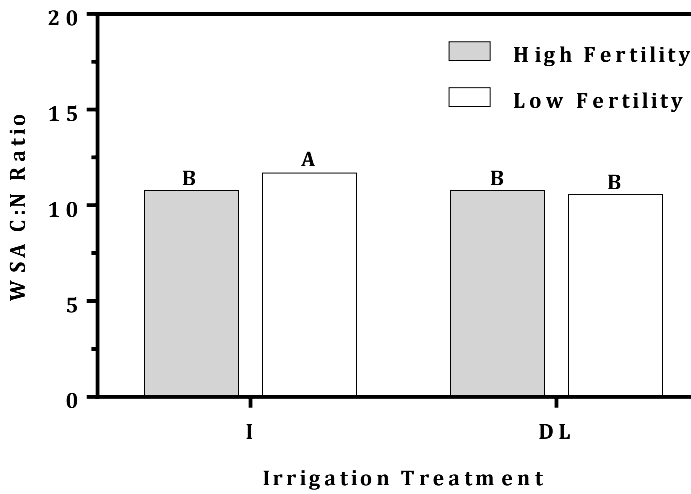

Fig. 12. Irrigation [irrigated (I) and dryland (DL)] and fertility (high and low fertility) effects on water-stable aggregate (WSA) carbon (C) to nitrogen (N) ratio. Different letters indicate significant differences between fertility treatments within the same irrigation treatment [least significant difference (LSD) = 0.42]. There were no significant differences between irrigation treatments within the same fertility treatment (LSD = 7.46).

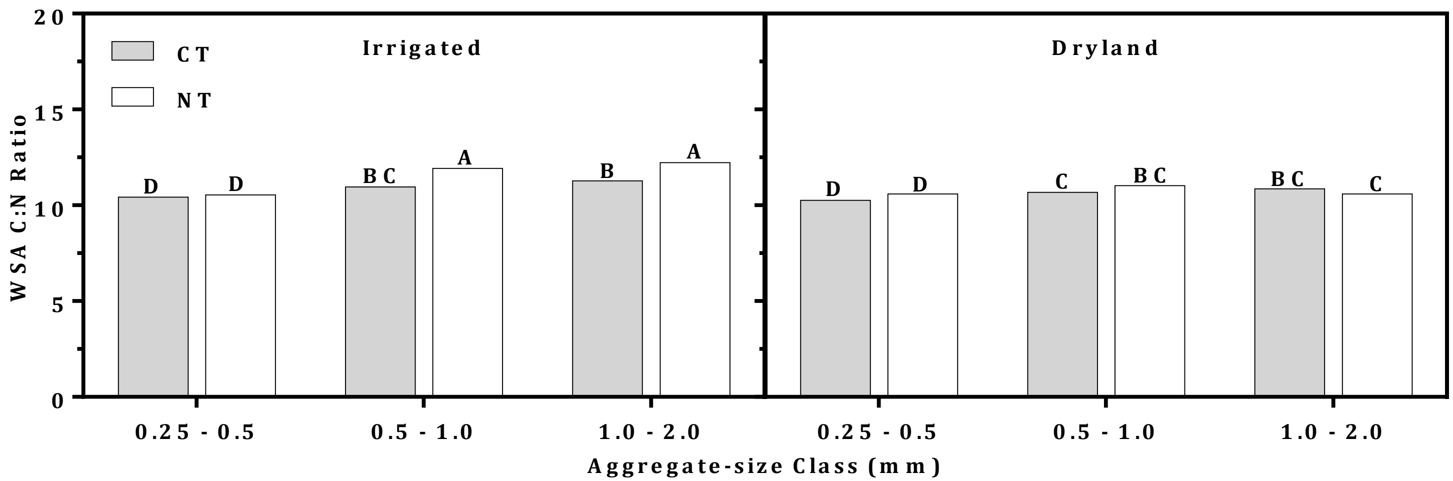

Fig. 13. Irrigation [irrigated (I) and dryland (DL)], tillage [conventional tillage (CT) and no-tillage (NT)] and aggregate-size class effects on water-stable aggregate (WSA) carbon (C) to nitrogen (N) ratio. Different letters indicate significant differences between aggregate-size classes within the same tillage-irrigation treatment combination [least significant difference (LSD) = 0.50]. There were no significant differences between tillage treatments within the same irrigation-size combination (LSD = 0.57) or between irrigation treatments within the same tillage-size combination (LSD = 10.5).

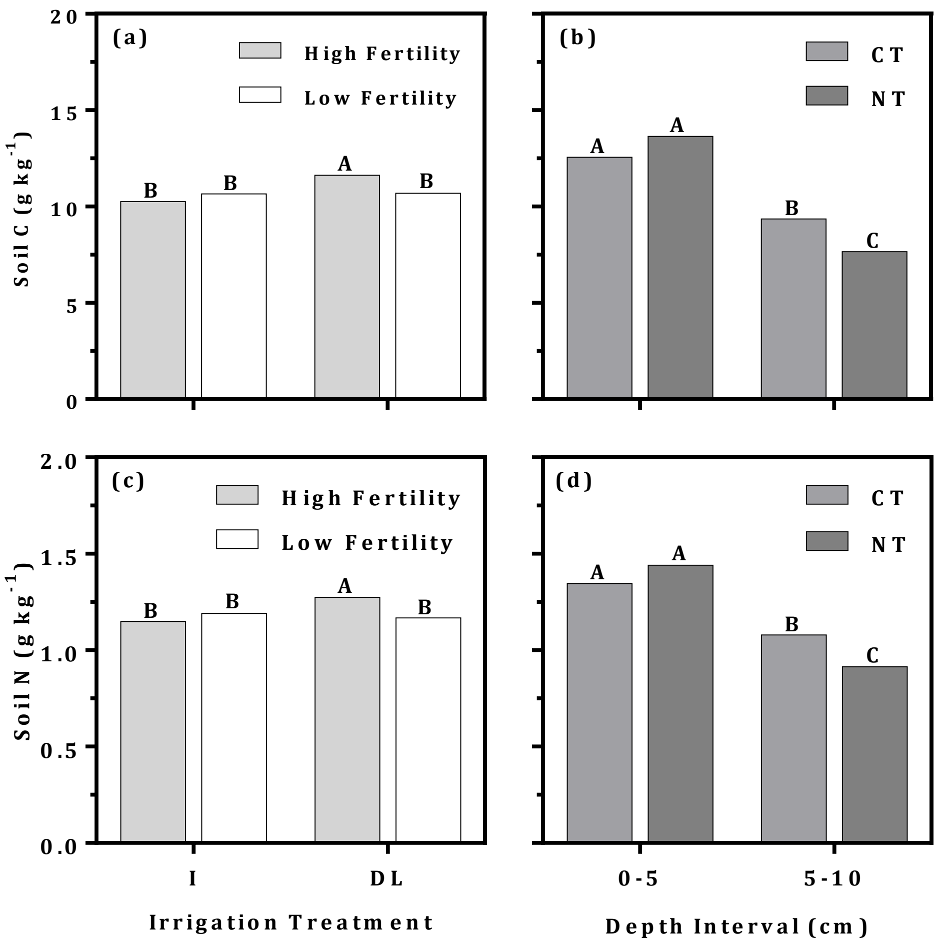

Fig. 14. Irrigation [irrigated (I) and dryland (DL)], tillage [conventional (CT) and no-tillage (NT)], fertility (high and low fertility), and soil depth (0- to 5- and 5- to 10 cm) effects on un-sieved, bulk-soil (Soil) carbon (C) and nitrogen (N) concentrations. **(a)** Different letters indicate significant differences between fertility treatments within the same irrigation treatment [least significant difference (LSD) = 0.72]. There were no significant differences between irrigation treatments within the same fertility treatments or between different irrigation and different fertility treatments (LSD = 17.6). **(b)** Different letters indicate significant differences between depth treatments within the same tillage treatment (LSD = 1.2). Different letters also indicate significant differences between tillage treatments within the same depth treatment or between different tillage and different depth treatments (LSD = 1.4). **(c)** Different letters indicate significant differences between fertility treatments within the same irrigation treatment (LSD = 0.08). There were no significant differences between irrigation treatments within the same fertility treatments or between different irrigation and different fertility treatments (LSD = 1.9). **(d)** Different letters indicate significant differences between different depth treatments within the same tillage treatment (LSD = 0.10). Different letters also indicate significant differences between tillage treatments within the same depth or between different tillage and different depth treatments (LSD = 0.12).

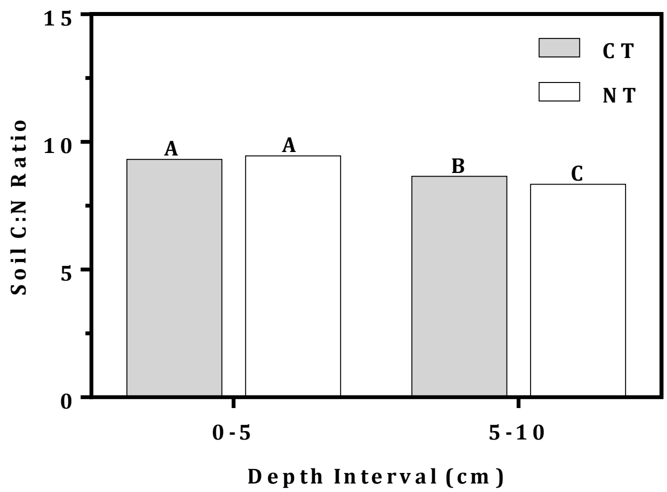

Fig. 15. Tillage [conventional (CT) and no-tillage (NT)], and soil depth (0- to 5- and 5- to 10 cm) effects on un-sieved, bulk-soil carbon (C) to nitrogen (N) ratio. Different letters indicate significant differences between depth [least significant difference (LSD) = 0.30] and tillage treatments (LSD = 0.28).

Conclusion

This field experiment demonstrated that there are long-term impacts of water- and residue-management practices on soil quality and soil carbon cycling. After nine years of consistent management of a wheat-soybean, double-crop system on a silt-loam soil in eastern Arkansas, soil respiration was affected by irrigation (irrigated and dryland), burning (burn and non-burn), tillage [conventional tillage (CT) and no-tillage (NT)], and fertility/residue level (high and low). Water-stable soil aggregate concentration was also affected by irrigation, tillage, and fertility/residue level.

Although the high-residue/N-fertilized treatment produced greater wheat residue in both years, water-stable soil aggregate concentrations were generally greater in the low- than high-residue treatment. Additionally, soil respiration was either unaffected or reduced by mineral-N additions. These results seem to indicate that long-term mineral-N additions may have reduced soil structural stability and may have negatively influenced soil biological function. However, there were no differences in N concentrations in the top 10 cm among treatment combinations prior to soybean planting in both years. Therefore, any direct effects on soil biological functions by mineral-N additions likely occurred during the wheat growing period.

The effect of tillage on soil respiration and soil aggregate stability was dependent on the water-management practice implemented. As was expected, CT decreased soil aggregate stability and increased soil respiration compared to NT under irrigated conditions. Surprisingly, CT had a positive impact on water-stable aggregate concentrations when coupled with dryland management. Although decreased soil structural stability from tillage is well-documented, the act of mixing organic matter into a soil with seasonally dry conditions may increase soil C storage over time. Without the sudden inundation of the soil by irrigation water, soil aggregates, which were mixed in with new organic matter, may have had a better chance of becoming stabilized by soil biota when the soil moisture levels were less limiting to soil biological function. Within the dryland treatment, soil respiration was also greater under CT than NT management during the exceptionally dry 2012 soybean growing season. Unlike in the dryland-NT treatment combination, soil biota had better access to substrate under dryland-CT management. However, biological consumption of soil OM was somewhat water-limited under dryland management during the soybean growing season, especially when temperatures were warm.

Total water-stable aggregate concentration was unaffected by residue burning. Estimated season-long CO_2 emissions were smaller following residue burning than when residue was retained. However, soil respiration was unaffected by burning during the first two years after the field study was initiated. It appears that residue burning may have a cumulative effect on soil C cycling over time. Decomposition processes likely respond much more quickly than the processes to form water-stable soil aggregates.

The results from this study indicate that the effects of residue- and water- management practices are not necessarily additive. Therefore, careful consideration of how one management practice may interact with another (e.g., irrigation and tillage) must be made to ensure the best management strategies for soil sustainability are implemented. Evidence from this study indicates that the combination of NT and low-fertility/residue treatments promotes soil C sequestration through the formation of water-stable aggregates, and through the reduction of CO_2 emissions, when irrigation is used. However, when dryland management is practiced, the combination of CT and low-fertility/residue treatments seems to help sustain soil microbial activity and increase the formation of water-stable aggregates.

Although processes related to soil C storage (i.e. soil aggregation and respiration) differed among treatments imposed, concentration of soil C in the top 10 cm was unaffected by any field treatment. Therefore, it can be reasoned that the soil in this field study may not have reached equilibrium levels yet. Since some treatment combinations produced less seasonal CO_2 and sustained greater concentrations of water-stable aggregates, differences in soil C among treatment combinations may eventually develop in the future.

Soybean production systems in Arkansas and across the United States are under pressure to produce greater yields, reduce production costs, and limit negative impacts on the environment. Not only can conservation agricultural practices help sequester C, the resulting increase in SOM, essential plant nutrients, soil aggregation, and biological diversity can alleviate the dependency on inorganic fertilizers and irrigation. In order to avoid future degradation of our agricultural soils, a balance of C inputs and losses must be achieved. This study demonstrates the decadal effects of common and alternative wheat-soybean, double-crop management practices on several soil quality parameters in the Mississippi River Delta region in eastern Arkansas. Therefore, the results from this study can help producers and policy makers make informed decisions regarding sustainable agricultural practices in similar wheat-soybean, double-crop systems in the United States.